University of Southampton

Head positions and head movements used by people following acute stroke

Kate Jupp

Doctor of Philosophy

Faculty of Medicine, Health & Biological Sciences
School of Health Professions and Rehabilitation Sciences

May 2005

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF MEDICINE, HEALTH & BIOLOGICAL SCIENCES
SCHOOL OF HEALTH PROFESSIONS AND REHABILITATION SCIENCES

Doctor of Philosophy

HEAD POSITIONS AND HEAD MOVEMENTS USED BY PEOPLE FOLLOWING ACUTE STROKE

By Kate Jupp

Impaired postural control is common post-stroke and characteristic of problems of instability experienced by individuals when upright, moving, reaching, and turning. Several studies have demonstrated a positive relationship between time to achieve independent sitting balance and rehabilitation outcome. Clinical experience and subjective reports in the literature suggest that recovery of coordinated head and trunk movements plays an important role in the recovery of sitting balance. No clinical tool was available to describe head activity (position and movement) following acute stroke. In this thesis, a tool with which to describe the head activity demonstrated by patients with stroke, the Head Activity Test (HAT), was developed. The HAT was used to describe the head activity used by patients and healthy adults during five seated functional tasks (upright sitting, visual search, communication, eating, and reaching). Two hundred and sixty-three descriptors of head activity were identified from five sources (literature, clinical practice, clinicians, researchers, and patients). The descriptors were short-listed to ten measurable tool items from which the HAT was designed. The video-based HAT (scored from 0-10) was validated against a laboratory-based 'gold standard', and intra- and inter-rater reliability established.

The head activity of 20 healthy adults (median age 49) was characterised using the HAT. The results showed a 'typical' pattern of head activity demonstrated by the healthy adult sample, characterised by a median HAT score of 10 (range 8-10), achievement and maintenance of an upright head and trunk position in sitting, dissociation of head and trunk movement, and the demonstration of head righting. Sixteen patients were recruited to a prospective observational study of head activity following stroke. Patients were assessed on three occasions (weeks one, three, and six). At week one, wide variation in head activity was demonstrated with HAT scores ranging from 0-10. HAT score was positively correlated with ADL ability ($p=.007$), motor impairment ($p=.006$), balance ($p=.002$), and sensory impairment ($p=.004$). Those with TACI and PICH had lower initial HAT scores than those with LACI, PACI or POCI ($p=.007$). Patients reported very limited insight into difficulties with head activity. HAT scores changed significantly between week one and week six ($p=.014$) with increasing numbers of patients achieving an upright head and trunk position, dissociating head and trunk movement, and demonstrating head righting reactions. Three-dimensional motion analysis was used to provide a more detailed description of the head activity demonstrated by both healthy adults and patients, during the HAT's most dynamically challenging task, the seated lateral reach.

The findings suggest that abnormalities of head activity are common following stroke, are associated with stroke type and severity, and show recovery in the first six weeks. Further studies are required to explore the impact of abnormalities of head activity on functional outcome, and the role of targeted intervention to improve head and trunk activity in the recovery of postural control and function.

List of Contents

List of Tables

List of Figures

Acknowledgements

A special thank you goes to everyone who participated in my studies: the patients, their relatives, and the staff of Christchurch Hospital Stroke Rehabilitation Unit.

I would also like to express my grateful thanks to the Stroke Association, which funded the therapy bursary award that made it possible for me to undertake this project.

Many thanks are due to those who shared their knowledge, expertise, and experience with me during the project. My thanks go firstly to Professors Ian Swain and Cath Sackley, whose early comments helped shape my work; I also wish to thank Chris Monk, who provided very patient bioengineering assistance and support. I am grateful to the staff of the Health and Rehabilitation Research Unit for their continued assistance and support. A special thank you goes to Malcolm Burnett for his technical assistance and for always coming to the rescue.

A sincere thank you is due to my supervisors, Dr Hamid Rassoulian, who provided early bioengineering supervision; Dr Vickie Yule, who stepped in at a very late stage and provided patient supervision at a very crucial point; and Professor Ann Ashburn, who provided unfaltering supervision and support, even when I threw several 'life events' in the path of this work.

And finally I thank my family and friends, without whose love and belief I could not have done this. My thanks to Charlotte for keeping me sane, to my mum and dad for their time and miles, to my husband Peter for being so calm and supportive, and last of all to Daniel and his yet to be born sibling – though you have taken up a great deal of time, you have given so much more, and provided me with the drive to finish.

List of Abbreviations

ACPIN	Association of Chartered Physiotherapists in Neurology
ADL	Activities of daily living
BBS	Berg Balance Scale
BI	Barthel Index
BIT	Behavioural Inattention Test
COP	Centre of pressure
CROM	Cervical range of movement device
CSP	Chartered Society of Physiotherapists
DOH	Department of Health
GCS	Global coordinate system
HAT	Head Activity Test
LACI	Lacunar infarct
LCS	Local coordinate system
MC	Marker configuration
NDI	Northern Digital Inc.
NHS	National Health Service
OCSP	Oxford Community Stroke Project
PACI	Partial anterior cerebral infarct
PICH	Primary intra-cerebral haemorrhage
POCI	Posterior cerebral infarct
RMA	Rivermead Motor Assessment
RM-A	Rivermead Motor Assessment - Arm
RM-GF	Rivermead Motor Assessment - Gross function
RM-LT	Rivermead Motor Assessment - Leg and trunk
TACI	Total anterior cerebral infarct
TIU	Tool interface unit
UVN	Unilateral visual neglect
WHO	World Health Organisation

Introduction

Introduction

For a physiotherapist working with patients following acute stroke, there were many questions about why patients move in a particular way, and whether and how to treat the 'abnormal' movement patterns remained unanswered. Particularly challenging were the apparently abnormal head and trunk movements demonstrated by many patients in the very acute phase of recovery, which appeared to be characterised by 'rod-like' movement of the head and trunk, with a lack of movement coordination and isolated head movement. A review of the literature revealed limited knowledge of head activity and its recovery following stroke, and the lack of an appropriate assessment tool with which to characterise the head and trunk activity demonstrated.

For this thesis a new video-based tool suitable for use in the acute clinical setting was developed. The new tool was then used in a series of investigations to describe the head activity (position and movement) demonstrated by people with and without stroke during a series of simple functional tasks. The primary aim of this work was to increase our understanding of abnormalities of head activity following acute stroke. As this work is early exploratory work in an area little researched, the secondary aim was to provide the preliminary evidence for further investigations of the role of head activity in the recovery of postural control and function, and the mechanisms underpinning abnormalities of head activity. The research process underlying this thesis is summarised below:

Chapter One

A review of the current evidence regarding the assessment, treatment, and impact of impairments of postural control and head activity following stroke is presented. The paucity of existing research into head activity following stroke is highlighted, the need for further research justified, and the hypotheses to be tested proposed.

Chapter Two

As no tool for the assessment of head activity following stroke suitable for use in the acute clinical setting was identified from the literature, the development of a new tool, the Head Activity Test (HAT), was undertaken. The four-phase development process followed is described.

Chapter Three

Establishment of the external criterion validity of the HAT by comparison with a three-dimensional 'gold standard' motion analysis system is detailed in Section 3A. In Section 3B, the intra- and inter-rater reliability of the HAT is presented.

Chapter Four

The first studies undertaken using the newly developed HAT to address the research questions and test the hypotheses proposed in Chapter 1 are reported, and the findings discussed. For Section 4A, the head activity of a small sample of healthy adults was investigated. For Section 4B, a prospective study was undertaken investigating the head activity and its recovery in a small sample of patients in the first six weeks following acute stroke. The characteristics of head activity demonstrated by both healthy adults and patients are discussed.

Chapter Five

The three-dimensional motion analysis data collected in the external criterion validity study (Section 3A) for the most dynamically challenging HAT task (lateral reach) is explored. A detailed description of the head and trunk positions and movement patterns used by healthy adults and patients during the reaching task is presented and discussed.

Chapter Six

In this final chapter the contribution of this thesis to knowledge is discussed. A new theory of the recovery of head activity following acute stroke is proposed. The implications for research and clinical practice are considered.

Chapter 1

Literature review

1.1 Stroke

A stroke is defined as a 'clinical syndrome of presumed vascular origin characterised by rapidly developing signs of focal or global disturbance of cerebral functions, with symptoms lasting more than 24 hours or leading to death' (WHO, 1978). Cerebral infarction accounts for 69% of strokes, primary haemorrhage 13%, sub-arachnoid haemorrhage 6%, and 12% are of uncertain type (Wolfe et al., 2002).

1.1.1 Classification

Different methods are available for the classification of stroke. These include neuro-radiology using computerised tomography (CT) and/or magnetic resonance imaging (MRI). Classification can also be made from the clinical presentation of the stroke, and a method increasingly used in the UK is the Oxford Community Stroke Project (OCSP) classification (Bamford et al., 1991). The classifications are: total anterior circulation infarct (TACI), partial anterior circulation infarct (PACI), posterior circulation infarct (POCI), lacunar infarct (LACI), and primary intra-cerebral haemorrhage (PICH). High levels of agreement between OCSP classification and neuroradiological findings have been reported (Lindgren et al., 1994).

1.1.2 Incidence and Prevalence

Stroke affects between 174 and 216 people per 100,000 population in the UK each year (Mant et al., 2004), and each year approximately 110,000 people in England and Wales suffer a first-ever stroke (Bamford et al., 1988). However, stroke prevalence at a national level is difficult to estimate accurately (Terent, 1993). Individual study prevalences vary widely, being influenced by the case finding methodology; the geographical areas studied, and change in incidence and survival rates of stroke patients (Shahar et al., 1995). The incidence of stroke increases exponentially with age, with approximately 90% of first ever strokes affecting people over the age of 55 (Bamford et al., 1988). Yet stroke can affect younger people too, and each year 10,000 people under 55 years of age and 1,000 people less than 30 years of age have a stroke (Office of National Statistics, 1998). The risk of stroke is reported to be higher among men, with one in four men having a stroke if they live to the age of 85, compared to one in five women, (Bonita et al., 1992). The risk of recurrent stroke within five years of first stroke is 30–43% (Mant et al., 2004).

Stroke is an important cause of hospital admission and accounts for some 4% of National Health Service (NHS) expenditure (Warlow, 1993; Department of Health, 2001). A substantial proportion of social care resources are also devoted to the immediate and continuing care of people who have had stroke (Department of Health, 2001). Reports of hospital admission rates vary from 55% (Bamford et al., 1986) to 78% (Wolf et al., 1993), but it is estimated that at any one time there are 25–35 patients with stroke as their primary diagnosis in the average general hospital (Rudd et al., 1999).

1.1.3 Mortality and Morbidity

Stroke is the single biggest cause of serious disability (Wolfe et al., 1996), and accounts for 11% of all deaths in England and Wales (Mant et al., 2004). Around 30% of patients die in the first month after a stroke, most in the first ten days (Department of Health, 2001). Although after a year 65% of surviving stroke patients can live independently, 35% are significantly disabled and many need considerable help with the activities of daily living (Bonita et al., 1997; Bamford et al., 1990; Department of Health, 1992, 2001). Approximately 5% of patients with stroke are admitted to long-term residential care (Health Care Needs Assessment, 1994). Data on the long-term survival of people with stroke suggests that between 51% and 53% have died within five to six and a half years following their stroke (Wilkinson et al., 1997, Dennis et al., 1993). These estimates of levels of mortality and morbidity, however, relate to a summary of all stroke types and different management approaches to the treatment of patients, and give only a very generalised picture. The estimates mask a more complicated relationship between clinical stroke sub-type and recovery, mortality, and recurrence of stroke (Warlow et al., 2001), and the impact of the management of stroke care on death rates, disability, and institutionalisation (Thorvaldsen et al., 1997; Stroke Unit Trialists' Collaboration, 2004).

1.1.4 Recovery

The 70% of patients who survive the initial stages of stroke generally show some improvement over time in their functional ability (Forster and Young, 2002). There is consensus that most recovery takes place in the first three months (Skillbeck et al., 1983; Wade et al., 1985). Beyond three months, recovery occurs at a slower rate (Skillbeck et al., 1983; Young and Forster, 1992), and with little research extending into the long term, the pattern of recovery after six months is less clear.

1.1.4.a Mechanisms underlying recovery of motor function

In recent years, with the development of non-invasive techniques to study brain function (including functional magnetic resonance imaging (FMRI), positron emission tomography (PET), and transcranial magnetic stimulation (TMS)), advances have been made towards understanding the relationship between cerebral reorganisation and functional recovery following stroke. Plasticity can be considered to refer to changes in brain networks that carry behavioural implication over time, and the link between brain structure and change in behaviour is firmly established in both animal and human studies (Ward and Cohen, 2004). However, what these studies do not tell us is how this reorganisation evolves. It is proposed that surviving elements of highly preserved neural systems, such as those involved in motor skill learning, are engaged to maximise functional motor recovery (Ward and Cohen, 2004). The success of cerebral reorganisation is therefore likely to depend on the integrity of the remaining areas. The length of time since stroke may also play a role, as early lesion-induced cortical hyper-excitability appears to facilitate cortical plasticity (Ward and Cohen, 2004). It remains unknown what the limits to brain reorganisation are, and to what extent rehabilitation interventions can influence such changes. The development of new effective therapeutic interventions relies on a greater understanding of the mechanisms underlying recovery of function, and how this knowledge might be translated into clinical benefit for patients. To date, the questions as to what drives the cerebral reorganisation and whether it is possible to modulate the reorganisation remain largely unanswered.

1.1.5 Rehabilitation following stroke

Effective stroke rehabilitation requires the coordinated skills of a wide range of professionals. There is now overwhelming evidence that a geographically identified in-patient stroke service for acute care and rehabilitation following stroke, with a specialist multidisciplinary staff, reduces death rates, disability, and institutionalisation (Kalra, 2000; Stroke Unit Trialists' Collaboration, 2004; Langhorne et al., 2004). There is no evidence to support the use of selection criteria for admission to a stroke unit (Wade et al., 2003), and recent evidence suggests those with more severe stroke have the most to gain (Stroke Unit Trialists' Collaboration, 2004).

1.1.5.a Physiotherapy practice in the treatment of patients following stroke

Despite the evidence supporting organised stroke services, much debate remains as to the best clinical approach to the rehabilitation of an individual patient, and significant variability exists in the interventions used. Differences in therapeutic approach centre around the type of stimuli used, the emphasis on task-specific practice, and the principles of learning drawn upon. Recently there has been a push away from the named approaches to treatment, as within these approaches there are common components of interventions (Pomeroy and Tallis, 2000; Lennon, 2000; Forster and Young, 2002). This thinking is supported by multiple clinical studies that have failed to demonstrate which therapy approach is optimal, and currently there is evidence only that any one of the current therapeutic approaches to movement re-education should be used (Pollock et al., 2004). Rather than the approach, it is the content of the therapy that influences outcome (Kwakkel et al., 1999; Parry et al., 1999; Pomeroy and Tallis, 2000). Evidence exists that structured repeated assessments of patients using valid and reliable assessment measures helps to identify problems (Wade et al., 1998). However, again reflecting the lack of evidence on the underlying approach to rehabilitation, there is no evidence to support any particular recommendation.

Expert opinion of current clinical practice in stroke rehabilitation gained from postal surveys has identified four underlying theoretical themes that guide physiotherapists in the assessment and treatment of patients following stroke: promotion of normal movement, control of tone, promotion of function, and recovery of movement with optimisation of compensation (De Gangi and Royeen, 1994; Davidson and Waters, 2000; Lennon et al., 2001).

Normal movement: Normal movement is characterised by efficient movement that is well ingrained within each individual's motor system. Despite the apparent logic behind comparing movement following stroke with the model of normal movement, limited evidence supports the effects of physiotherapy on restoring normal movement (Intercollegiate Working Party for stroke, 2004; Pommeroy and Tallis, 2000). Shumway-Cook and Woolacott (1995) suggest that judgements about therapeutic goals should not always be made solely on the basis of quality of movement, as the solutions to patients' problems depend on the interaction of the individual, the task and the environment. Emerging evidence suggests that task-specific training, giving the patients the opportunity to repeatedly practise functional activities, may be a major element in improved outcomes (Langhorne et al., 1996; Kwakkel et al., 1999; Wu et al., 2000). Pollock et al. (2004) stress the need for future studies to clearly define and describe specific rehabilitation therapy techniques and explore their effectiveness during task-specific treatments.

Tone: Though control of tone was identified as a key theoretical belief of current physiotherapy practice for patients with stroke, there is minimal evidence of the benefits of physiotherapy on the control of tone (Intercollegiate Working Party for stroke, 2004; Mayston, 2000), and more research in this area is required.

Function: In the promotion of function, recent research confirms that experienced physiotherapists give the practice of tasks high priority (Lennon et al., 2001; Lennon and Ashburn, 2000). Lennon (2003) highlighted the confusion among therapists regarding the automatic transfer of improved movement performance into function. Although the consensus of therapists is that patients need to practise tasks out of therapy, concerns exist that independent practice may lead to abnormal movement and tone. Thus the degree of task and context specificity within current practice is subject to debate. With current evidence suggesting that the practice of motor skills needs to be both task- and context–specific, the merit of 'preparing' the patient for function has been put under scrutiny. The preparation of a patient prior to practising functional tasks is a focus of the Bobath concept, the preferred treatment approach in the UK (Sackley and Lincoln, 1996; Lennon et al., 2001). Research has highlighted practice and feedback as two crucial issues for therapists (Lennon, 2000). Evidence from motor learning research is currently based on healthy adult populations and much more research is required to determine the most effective ways to structure task practice and provide feedback for patients with stroke. The assumption that practice outside of therapy may make movement patterns more abnormal needs further investigation.

Recovery: In Section 1.1.4.a the evidence that the CNS is plastic and the link between plasticity and change in behaviour were presented. The evidence of neuroplastic change suggests that recovery of movement and function should be the main aim of therapy, rather than the promotion of compensation. However, evidence for specific therapy-induced changes in brain recovery remains sparse (Pomeroy and Tallis, 2000). Compensation is not well defined in the literature. It can be viewed as both a positive and negative contributor to movement dysfunction following brain damage (Edwards, 2002). Current evidence suggests therapists should not prevent a patient from moving unless alternative strategies can be used to achieve the same goal (Mayston, 2000). A balance between the re-education of normal movement patterns and the promotion of desirable compensation is not surprisingly currently advocated (Shumway-Cook and Woollacot, 1995; Edwards, 2002). Further research is required to identify what the balance is. In addition knowledge is needed of the impact of factors such as the patient's condition (e.g. pre-morbid health status, and severity of stroke), the timing of the intervention, and the patient's and carer's needs and preferences, on tilting the balance in either direction.

Running alongside the therapy content debate is the question about the amount of therapy required. To date there is little evidence as to the optimum amount of therapy, and importantly the question as to whether there is a minimum threshold remains unanswered. The results from the few studies undertaken are mostly confounded, as the services giving more therapy are usually the most organised and expert. The current recommendation from the National Clinical Guidelines for Stroke (Intercollegiate Working Party for stroke, 2004) is that patients should undergo as much therapy appropriate to their needs as they are willing and able to tolerate. There is also little evidence as to the best timing of therapy input. Many of the studies assessing the effectiveness of specific interventions have looked in the sub-acute or more chronic phases of the recovery process. Few studies have looked at intervention in the very acute phase of recovery (first six weeks), yet it is frequently at this stage that recovery is most rapid, patients are most susceptible to change, and rehabilitation input is most intensive. The current recommendation from the National Clinical Guidelines for Stroke (Intercollegiate Working Party for stroke, 2004) is that patients should be assessed by a physiotherapist with expertise in neuro-disability within 72 hours of admission.

1.1.5.b Contemporary rehabilitation approaches

Current evidence suggests new therapy interventions are beginning to emerge reflecting a move away from the traditional named therapy approaches of the physiotherapy pioneers, towards a focus on the components of therapy. For example, recent research suggests that the practice of motor skills needs to be both task- and context-specific (Kwakkel et al., 1999). Evidence exists for improving reaching (Trombly and Wu, 1999; Wu, 2000) and walking speed (Kwakkel and Wagenaar, 2002) with task-specific training, and current clinical guidelines state "task specific rather than impairment focused should be used for the specific objectives of improved reaching for objects, and improved walking speed" (Intercollegiate Working Party for stroke, 2004). As research into task-specific training continues it is likely that the number of tasks with evidence to support task and context specificity of training will increase. In the first (recently published) systematic review of the efficacy of physiotherapy interventions related to improving functional outcome following stroke (Van Peppen et al., 2004) all effective studies were characterised by focused exercise programmes within which the functional tasks were directly trained.

Though new therapies, with evidence to support their use, are slowly emerging, the emphasis has been on the treatment of upper limb function and gait in patients with sub-acute and chronic stroke. A growing gap is evident in the development of novel therapy interventions aimed at the treatment of postural control and movement deficits in the very acute stages of recovery, and for those with the most severe stroke, to improve functional outcome. This is despite the evidence that most recovery takes place in the first 12 weeks following stroke (Skillbeck et al., 1983; Wade et al., 1985) and those with enduring disability require costly long-term continuing care (Department of Health, 1992; 2001).

1.1.5.c Limitations of physiotherapy intervention studies

Ashburn et al. (1993) suggest that deficiencies in research design and methodologies have compromised the quality of many of the studies investigating treatment efficacy, and may explain many of the equivocal findings. The authors highlight the failures to ensure that content and quantity of interventions followed guidelines, that interventions were targeted and documented, and that along with outcome measures they matched the study and treatment aims. The use of small sample sizes, the lack of transparency in patient selection, the frequent large range in time since stroke, the assessment of physical performance unrelated to function, and the disregard for systematic dropouts in these studies have also been recurring limitations. Small sample sizes have also meant that studies cannot divide the sample according to type and severity of stroke, or the stage of the recovery phase. Evidence supporting the use of physiotherapy to improve performance of regular daily activities, has predominantly come from studies starting early after stroke (Kwakkle et al., 2004), yet frequently studies use samples of patients with sub-acute and chronic stroke.

The lack of randomisation and the use of un-blinded observers have both contributed to potential study bias, and a tendency to overestimate observed effects (Van Peppen et al., 2004). The diversity of the interventions studied and the selected outcomes has meant that the pooling of randomised controlled trials (RCT) has been limited. This problem was highlighted by Van Peppen et al. (2004). Despite the relatively large number (151) of randomised (123) and controlled (28) trials, identified in the systematic review, the authors frequently had to use a qualitative best-evidence synthesis to analyse the results. The diversity of outcomes used is at least in part due to the lack of availability of appropriate measurement tools. The limitations encountered by studies to date highlight the need for more high-quality RCTs, and for a consensus about using the same core set of measures in stroke rehabilitation studies in the future. The lack of comparability of many of the interventions and outcomes emphasises the merits of multi-centre collaborative research. More positively, Van Peppen (2004), in systematic review of physiotherapy interventions, identified a significant association between year of publication and PEDro Score (methodological quality) suggesting a recent increase in the awareness of researchers for high quality studies.

1.1.5.d Hierarchical recovery

Hierarchical patterns of recovery of mobility milestones following acute stroke have been identified in the literature (Partridge et al., 1987) and (Smith and Baer, 1999).

In the study by Smith and Baer (1999), the time taken from onset of stroke to achieve four mobility milestones (one-minute sitting balance, 10-second standing balance, a10-step walk, and a 10-meter walk) was investigated in 238 patients. For all subjects the median time to achieve the milestones was as follows: one-minute sitting balance, day of stroke; 10-second standing balance, three days; a 10-step walk, six days; and a 10-meter walk, nine days. The work by Smith and Baer (1999) emphasises the potential of simple standard measures of basic physical ability in the rehabilitation of patients following stroke, including improved goal setting and communication between professionals.

1.1.5.e Prediction of functional outcome

The methodological flaws in published prognostic research have contributed to the lack of accuracy in predicting functional outcome after stroke (Smith and Baer, 1999). One frequent limitation is the method of selection of patients for prognostic studies. In a review of 33 studies relating to functional recovery from stroke, adverse prognostic indicators of functional recovery were identified as persistent urinary and faecal continence, visuo-spatial deficits, older age, previous stroke, and poor sitting balance (Jongbloed, 1998). Such variables however, are often non-specific markers of stroke severity, and tend to be strongly interrelated (Gladman et al., 1992).

The recovery of functional mobility has been linked to classification of stroke (Smith and Baer, 1999). On average patients with PACI, LACI, and POCI achieve the mobility milestones of sitting, standing, stepping and walking prior to those with PICH and TACI. The median time for patients with PACI, LACI, and POCI to achieve sitting balance was on the day of the stroke, while individuals with PICH took a median of seven days, and those with TACI a median of 11 days. The authors propose timescales for achievement of key mobility milestones (based on the 75^{th} percentile data). It must be stressed, however, that the sample in the study was of patients requiring in-patient physiotherapy, and whether the data is representative of an entire stroke patient population is not known.

Several studies have demonstrated a positive relationship between time to achieve sitting balance and rehabilitation outcome (Wade et al., 1984; Bohannon et al., 1986; Lowen and Anderson, 1990; Sandin and Smith, 1990; Partridge et al., 1993; Morgan. 1994; Smith and Baer, 1999). Despite differences with respect to how sitting balance is measured (for further details see Section 1.3.1) the prognostic importance of sitting balance has been established. In the study by Sandin and Smith (1990) the importance of serial measurement of sitting balance to indicate which patients will do well during stroke rehabilitation was reported. Of the 24 consecutively admitted patients with stroke, those with initial good sitting balance *and* those with improvement in sitting balance had significantly higher Barthel scores at four weeks than those with poor sitting balance. More recently a positive correlation between trunk control at 14 days post stroke (measured using the trunk control items of the Postural Assessment Scale for Stroke Patients (PASS-TC)) and comprehensive ADL ability at six months was demonstrated by Ching-Lin et al. (2002).

The importance of recovery of head control in the prediction of functional outcome. though often stated by clinical experts, is yet to be confirmed by scientific research. Though types of stroke, time to achieve sitting balance, and trunk control have been identified as important prognostic factors, none is accurate at the level of the individual patient. For predictions to be clinically useful they need to be accurate for an individual, and not just for large patient groups.

1.1.6 Summary

Evidence indicates that stroke is the leading cause of long-term disability worldwide. Functional recovery from stroke follows a hierarchical pattern, and most takes place in the first three months. In the rehabilitation of patients following stroke, organised specialist stroke rehabilitation is known to be beneficial. However, the most effective approach to rehabilitation, and specifically to early intervention for postural control deficits, is currently not known. Evidence suggests that early recovery of sitting balance and trunk control is associated with a good functional outcome. However, evidence is still weak for effective interventions in the improvement of functional outcome following stroke. For the development of more effective treatment strategies, a better theoretical understanding of the underlying mechanisms of disordered movement coordination is needed.

1.2 Postural control following stroke

Impaired postural control is a common feature of stroke (Morgan, 1994). With postural control being an integral component of function and the foundation for all voluntary movement (Massion and Woollacot, 1996), the importance of rehabilitation of postural control following stroke is undisputed. However, limited research has meant that to date, specific targeted early interventions aimed at improving postural control are yet to be identified. If such therapies are to be developed, an understanding of the mechanisms underlying postural control is required. In this section the evidence of the mechanisms underpinning postural control, and how they are affected by stroke, specifically the role of the head in postural control, is reviewed. The importance of head activity in the recovery of postural control and function following stroke is proposed.

Pollock et al. (2000) stressed the importance of universally accepted clinical definition of postural control for the accurate assessment of patients' problems. The authors defined postural control as the 'act of maintaining, achieving or restoring a state of balance during any posture or activity'. This definition will be used throughout this thesis.

1.2.1 Determinants of normal postural control

A multi-dimensional and flexible postural control system is required to ensure stability of the body during widely differing activities whether stationary, preparing to move, in motion, or preparing to stop (Wade and Jones, 1997). Postural control acts to counteract gravity by the control of postural tone, by stabilising the body's centre of gravity with respect to the ground, and by providing and adjusting mechanical support to both internally and externally generated perturbations. The vestibular, visual, and proprioceptive systems are the primary sensory systems involved in the maintenance of balance, though auditory and autonomic systems also play a role (Konrad et al., 1999). The relative importance of the individual systems are yet to be fully understood, but are thought to change depending on the task demands (Horak et al., 1989; Maki and Whitelaw, 1993; Horak and Deiner, 1994; Inglis et al., 1994). The convergence of sensory information allows for different sensitivities and ranges of the individual systems. Wade and Jones (1997) suggest that it is the nature of the integration of the systems that is key to a better understanding of how the postural system works.

The demands on the balance control system during any functional task are determined not only by the task being undertaken but also by the environment in which it is performed (Huxham et al., 2001). The task and the environment influence the amount of information that needs to be processed to maintain balance and achieve the motor goal (Gentile 1987). In order to meet the biomechanical challenges of the task and the environment, the balance control mechanism requires adequate sensory input, efficient central processing, and an intact neuromuscular system (Horak et al., 1989).

The selection of sensory information to be processed and integrated with motor commands occurs at a cortical level. In the interpretation, sensory information is compared to spatial memory and previous learned responses (Konrad et al., 1999). This central processing is a prerequisite to the accurate determination of body position with respect to gravity and the environment, the adaptation of sensory inputs to changes in task demands, and the anticipation of instability based on prior experience. Cumulative evidence suggests that sensorimotor integration takes place at multiple levels within the central nervous system to generate appropriately timed and scaled movements of the eyes, head, trunk and limbs (Lamontagne et al., 2001).

1.2.1.a Role of the head in normal postural control

Throughout this document the term head activity will be used to mean a head position and/or head movement. As trunk position and movement in part determine head activity, and movement occurs at the cervical spine, combined head and trunk positions and movements are included in this definition. Head activity is context specific, and the task during which the head activity occurs needs to be reported if the head activity is to have meaning.

1.2.1.b Biomechanics underlying head activity

The head represents 8% of total body mass (Winter 1990), and has a centre of mass (CoM) projection close to that of body centre of gravity, meaning that head motions induce minimal displacement of body CoM. However, head motion involves intense stimulation of sensory organs located in the head and neck, and many reflexes such as the vestibular ocular reflex (VOR), the cervicocollic reflex (CCR), and the vestibulocollic reflex (VCR) are active during head motion (Allum et al., 1997). Factors such as the viscoelastic properties must also be taken into account in the control of head movement (Peterson et al., 2001).

1.2.1.c Sensory components

The visual and vestibular systems are well known to play a role in postural control (Igarashi et al., 1970; Marchand and Amblard, 1984; Marchand et al., 1988; Assiante et al., 1989; Assiante and Amblard, 1993). The orientation of the body relative to the environment plays a key role in the interpretation of the information from the visual and vestibular systems on the state of the environment. Head movement strategies play an active role in gaze stabilisation, and adjustments of head movement strategies occur according to environmental circumstances (Crane and Demer, 1997). Humans have a relatively large occulomotor range of approximately ±45° providing a substantial amount of flexibility in the relative contributions of eye and head movements available for use in gaze shift strategies (Goosens and Van Opstal, 1997). There is evidence to suggest that the head movement strategies used during gaze shift may be task dependent (Pelz et al., 2001). Findings have suggested an independent control of the eye and head motor systems, but with a degree of coupling between them (Goosens and Van Opstal, 1997, Guitton and Volle, 1987).

This could explain dissociated eye and head movements, for example differences in gaze shift strategies to auditory and visual stimuli (Goosens and Van Opstal, 1997), and the ability of humans to execute gaze shifts with and without head movements (Ron and Berthoz, 1991).

Head position and movement are also important in the interpretation of vestibular information. Unlike the somatosensory or visual systems, the vestibular afferent signals do not preserve their modality-specific information within the central nervous system. Inputs from the somatosensory and visual systems are essential in the interpretation and use of the vestibular signal.

1.2.1.d Head stabilisation

Mechanisms for head stabilisation in space and with respect to the trunk have been investigated in several studies (Horak et al., 1994; Keshner and Peterson, 1995; Maurer, 2000; Peterson et al., 2001). These studies have largely involved externally generated perturbations to the head, trunk or body. Little is known about head stabilisation during simple functional tasks. Head stabilisation can be considered in terms of head stabilisation in space (with respect to gravity), and head stabilisation with respect to the trunk (Assiante and Amblard, 1993). Head stabilisation in space reduces the magnitude of perturbations to the sensory systems located in the head (Pozzo et al., 1990). During walking, healthy subjects stabilise the head in space to maintain gaze and visual acuity (Grossman et al., 1988; Mulavara et al., 2002), and optimise vestibular processing (Roberts, 1976). Head–trunk coordination helps organise the sensory inputs from the visual, vestibular, and somatosensory systems to maintain equilibrium. Head–trunk coordination has been demonstrated in subjects performing various static and dynamic tasks, including standing (Nashner, 1985) and walking (Bril and Ledebt, 1998). The studies looking at head stabilisation in space and head position relative to the trunk add to the knowledge of the role the head plays in balance control.

1.2.2 The effect of stroke on postural control

Impaired postural control is a common feature of stroke, and characteristic of the problems of instability experienced by individuals when upright, moving, reaching or turning. It is caused by a complex interplay of motor, sensory, and cognitive impairments, and the sensorimotor integration circuitry itself may be damaged (Lamontagne et al., 2003). Deficits are frequently seen in patients' ability to recruit and sequence movement patterns, and monitor resulting postural changes. Following stroke, impairment of motor function is one of the most common problems encountered by the patient (Wade et al., 1985). Movement deficits are characterised by weakness of specific muscle groups (Adams et al., 990); altered muscle tone (Wiesendanger, 1990); abnormal postural adjustments (Di Fabio et al., 1986); abnormal movement synergies (Brunnstrom, 1970), lack of joint mobility (Carr and Shepherd, 1987; Michaelson et al., 2001); abnormalities in timing components of movement patterns (Carr and Shepherd, 1987; Archambault et al., 1999, Cirstea and Levin, 2000, Michaelson et al., 2001); fixation of specific body segments (Campbell et al., 2001); loss of inter-joint coordination (Levin, 1996; Cirstea and Levin, 2000); the inability to adapt movements to changing task demands (Dichgans and Diener, 1989); and impaired selection and control of specific movements from the repertoire of possible movements.

Stroke can also result in a deficit of a wide range of cognitive processes that can adversely affect a patient's ability to participate in therapy, perform activities of daily living, and ultimately live independently. Impairments of attention are probably the most pervasive cognitive deficit following stroke (Intercollegiate Working Party for stroke, 2004). Deficits of attention have been shown to be associated with poor performance on measures of motor control, balance and function (Brown et al., 2002; Hyndman and Ashburn, 2002). Another cognitive deficit frequently seen following stroke is uni-lateral neglect. Estimates of the prevalence of neglect vary widely (between 20–80% (Stone 1993)), and reflect different assessment techniques, and timing. Patients with neglect generally have a less favourable recovery outcome than those without neglect (Kinsella and Ford, 1980; Denes et al., 1982; Wade et al., 1983; Henley et al., 1985; Fullerton et al., 1986).

A sub-group of patients with atypical balance responses have been described as 'pushers'. The 'pushing phenomenon' was described by Davies (1985) as a reluctance of the patient to accept weight through their unaffected side, manifesting as an active 'push' towards their hemiplegic side. Ashburn (1997) quantified the weight distribution of 'pushers' in sitting, and confirmed the asymmetrical posture of these patients. 'Pushing' behaviour has been noted for adversely affecting achievement of mobility milestones (Ashburn 1997), recovery of function, and increasing hospital length of stay (Pederson et al., 1996). Unfortunately there are no universally accepted criteria for defining a patient as a 'pusher', making estimates of the incidence of the phenomenon problematic. Pederson et al. (1996), found the incidence to be 10% in their hospital sample. Ashburn et al. (1997) suggest that 'pushing' is associated with severe sensorimotor deficit and unilateral neglect, but that severity of the lesion alone cannot explain the phenomenon.

More recently, research has investigated the presence of a biased postural vertical in patients following stroke. Kanarth and colleagues (2000) investigated the subjective visual vertical (SVV) and subjective postural vertical (SPV) in pushers and non-pushers following first-ever stroke. No difference in SVV was found. Pushers had a significant difference in SPV in the 'without vision' condition, perceiving vertical as being towards the lesion side (median 18°). An interesting finding of this work is the normal SPV of the pushers, with the visual cues of vertical. From both clinical experience and subjective reporting of 'pusher' behaviour, these patients do not seem to be able to use visual information in routine daily activities. No direct relationship between subjective visual vertical and disturbed body posture has been found (Kanarth et al., 2000; Yelnik et al., 2003). The relationship between SVV and SPV and disturbed body posture such as 'pushing' remains unclear. Abnormalities of SVV and SPV indicate a generalised disorder of vertical perception but are not by themselves the cause of the 'pushing' behaviour (Perennou and Bronstein, 2004). More research is required to answer the question as to whether postural disorders following stroke are caused by a misrepresentation of verticality, an impaired postural stabilisation, or a combination of the two.

1.2.3 Head Activity following Stroke

Despite the importance of the role of head activity in postural control and consequently function, very little work has been undertaken to investigate head activity following stroke.

1.2.3.a Range of cervical motion

A prerequisite to the meaningful assessment of head activity is a measure of the range of cervical motion. A biomechanical limitation in range needs to be ruled out if abnormalities of head activity are to be considered a consequence of stroke. One criticism of the few studies available looking at head activity has been the failure to measure the range of cervical motion (e.g. Campbell et al., 2001; Altorfer et al., 2000).

Only one study looking at the range of cervical spine movement in people with stroke was found. Tsur and Solzi (1996) sought to determine if differences existed between the sound and hemiplegic sides in the available range of active rotation and lateral flexion. The movements of 38 patients at least six months following stroke and 29 controls were measured. Methodological weaknesses of the study (including no reliability or validity data for the measurement tool used) mean the results must be treated with extreme caution. However, a significant difference was found between sides for lateral flexion in the stroke patient group, with a reduction to the sound side. The difference was greater in patients at least one year post stroke. Unfortunately, the authors did not report the differences in actual range of movement between the control and stroke patient group. Despite its weaknesses, the study raises the possibility of altered range of cervical motion following stroke impacting on head activity.

1.2.3.b Weakness of head and trunk movement

Weakness of 'head turning' towards the hemiplegic side has been subjectively reported for nearly a century (Beevor 1909). Objective measurement has however, only been reported by Mastalgia and colleagues (1986) in a myometry study, following forty patients (and 40 aged matched controls), less than six months following stroke. In the patient group, the strength of cervical rotation to the two sides was significantly different. Patients with non brain stem stroke (36) had weakness of head rotation to the hemiplegic side, and those with brain stem lesion (4) had weakness to the sound side. No difference between sides was reported in the control group. In those with a reduction in strength in head rotation the interside difference was 20 Newtons or greater. Whether this weakness impaired functional movement, either directly or as a result of fatigue, was not answered by this work. Lamontagne et al. (2001) suggest neck muscle weakness is not a plausible cause of altered voluntary head movement patterns following stroke because of the low forces required.

As head activity is inextricably linked to trunk activity, weakness of trunk muscles also has the potential to impact on head activity. Davies (1985) and Bobath (1990) both emphasise the sensorimotor loss and the asymmetry in trunk control following stroke. The role that the strength of the trunk muscles plays in the impairment of trunk control has not been established and conflicting results are reported: Dickstein et al. (1999; 2000) found no significant difference in abdominal activation between patients with stroke and controls; Bohannon et al. (1995) and Tanaka et al. (1997) found bilateral deficits in trunk muscles following stroke; Palmer et al. (1996) and Horak et al. (1984) found unilateral deficit in trunk muscles in their role in postural control. Different methods of testing muscle strength (EMG and isokinetic dynamometer), testing patients at different time points in recovery, and the different assessment tasks have contributed to the conflicting results. Further investigation of the impairment of trunk muscle activity and the impact on postural control and function is required.

1.2.3.c Head and trunk alignment

Head and trunk alignment, and asymmetry of weight distribution following stroke have been described in detail for decades by physiotherapy pioneers. The ability to achieve a sitting position with an aligned head and trunk is seen as a prerequisite to 'efficient' functional movement by the physiotherapy pioneers (Brunnstrom, 1970; Knott and Voss, 1968; Carr and Shepherd, 1987; Bobath, 1990).

Before patients are able to independently achieve lying and sitting positions, positioning is a commonly recommended component of rehabilitation (Bobath, 1990; Lynch, 1991; Davies, 1994). A national survey of physiotherapists' aims and practices of positioning stroke patients identified positions recommended by physiotherapists (Chatterton et al., 2001). In the positions identified (side lying, supine, half lying, sitting in wheelchair and armchair, and forward lean sitting) the alignment of proximal body parts, including the head, was identified as most important. The most common aim of positioning was modulation of muscle tone. Through the use of modified focus groups Tyson and De Souza (2003) reported the development of a clinical model to assess posture and balance of patients following stroke. Alignment and movement of body segments were identified as factors limiting patients' ability to perform a function, including position of the head and neck and the use of a head righting response. These reports of current clinical practice and clinicians' opinions suggest that problems of head and trunk alignment are a common feature following stroke that can impact on function; evaluative research, however, is yet to be undertaken.

Taylor et al. (1994) investigated the relationship of symmetry of trunk posture in sitting with motor function and unilateral neglect in 38 patients following acute stroke. Patients leaning towards their affected side at six weeks following stroke (nine) had poorer gross functional outcome scores (and eight had unilateral neglect) compared with those with their trunk in the midline or towards their unaffected side.

1.2.3.d Head stabilisation

Largely through the influence of the Bobath concept, righting reactions (described as automatic reactions which produce orientation of the head in space) have played a part in therapeutic interventions in the treatment of postural control and balance deficits in patients with stroke (Bobath, 1990; Davies, 1990; Edwards, 1996). Only one study was found investigating the presence of head righting reactions and head stabilisation in patients with stroke. Campbell et al. (2001) used a 3D motion analysis system (CODA) to investigate the head and pelvic movements of five patients with acute stroke (< 6 weeks) during a seated dynamic lateral reaching task. Comparisons were made to the movements used by healthy adult controls (53). A significant difference in the range of head rotation between the patients and controls was recorded. All patients with stroke rotated their heads in the direction of the reach (mean 12°), and demonstrated head extension. In contrast control subjects tended to move their heads in the counter direction (mean -11°), and predominantly demonstrated head flexion. The authors suggest the difference was a result of the lack of ability of the patients with stroke to use a head counter-balancing strategy. In addition to the patterns of head movement differing between the stroke and control group a significant reduction in the range of head movements was found in the patients with stroke. The results supported the study hypothesis that patients use the greater stabilisation of head on body fixation, rather than head in space, to increase their awareness of a vertical reference frame. The results from this study are also in agreement with the suggestion by Nashner (1985) that in the absence of good information about gravity from the vestibular system, or in an attempt to simplify head trunk coordination, the head may be stabilised with respect to the trunk. With such a small patient sample caution has to be taken in generalising the results, but this study provides an important launching pad for future work in this area. One consequence of the lack of research into the role of head stabilisation and head righting reactions in patients with stroke is that the relationship between head righting and stabilisation and performance of functional tasks is not clear (Hirschfield and Frossberg, 2001).

1.2.3.e Head activity during functional tasks

Very little research has investigated the head activity used by patients following stroke during functional tasks. The lateral reaching task in the study by Campbell et al. (2001) (reviewed in the previous section) can be considered a functional task. The results from this study suggest that patients may have difficulty dissociating segmental movements of the head, trunk, and pelvis, and the authors propose that this may have implications for the ability to make postural changes during voluntary movements, which could result in poorer control of balance and function. The only other study found looking at head activity following stroke was that of Brady and Mackenzie (1999), investigating the gesture use (including head gestures) of eight patients one month and six months following stroke. Gestures were analysed from video recordings using both modality and functional categories (Wallbott, 1995). Unfortunately no reliability data for the gesture analysis was reported. Few changes in the use of gesture during conversation between one and six months were observed, but interestingly a significant increase in head movements was seen in three out of the six conversation samples. Whilst acknowledging the very small sample the authors make a tentative suggestion that the increased head activity may reflect a more coordinated use of 'emphasis adding' gestures. There is evidently a gap in the literature relating to the head activity used by patients following stroke during functional tasks. A description of head activity at this level, reflecting the current emphasis of intervention aimed at improving functional outcome following stroke (task and context specific training), is clearly needed.

1.2.4 Summary

It is known that postural control is the foundation for voluntary movement and an integral component of function. Postural control problems are a key feature of stroke and can result from alterations of postural tone, deficits of motor control, sensory impairment, perceptual problems, and deficits of sensorimotor integration. Head activity plays a key role in normal postural control. Limited research and clinical experts have described abnormalities of head activity as a frequent early consequence of stroke. The importance of rehabilitation of postural control following stroke is undisputed. Evidence suggests a positive correlation between recovery of early postural control (sitting balance and trunk control) and good rehabilitation outcome (Sandin and Smith, 1990; Morgan, 1994; Smith and Baer, 1999: Ching-Lin et al., 2002). However, to date no research has been undertaken to investigate the recovery patterns of head activity following stroke, or the relationship between level and recovery of head activity, postural control, and functional outcome.

1.3 Measurement of head activity following stroke

The consequences of postural control deficits on patients with stroke have been highlighted. The role that head activity plays in postural control was described, and the importance of head activity in the recovery from stroke has been proposed. In the following sections the assessment of head activity in patients with acute stroke is considered. Methods used by other researchers are reviewed and key issues arising from the literature summarised. In light of the findings, the requirement for a new assessment tool suitable for the evaluation of head activity in patients with acute stroke is proposed.

Measurement of head activity presents several methodological and technological problems. Head movement is complex, and involves multiple vertebrae resulting in many possible ways of executing a given movement (Medendorp et al., 1998). The location of the eyes, the importance of the face in social interaction, and the relatively spherical shape of the head further complicate the use of motion analysis equipment. It is also argued that for measurement of head activity to be meaningful both the context of the head activity and the activity of the trunk need to be taken into account. The relatively few studies that have been undertaken to measure head activity are probably more reflective of these measurement difficulties than of the importance of head activity measurement. A literature search on the methods and tools used to measure head activity following stroke revealed just how little has been published. The absence of a clinical measurement tool highlights, in part, why head activity is so infrequently reported in studies looking at recovery of motor function and postural control following stroke.

Clinical experience suggests that head activity is dependent on the coordination of other body segments, particularly the trunk, and that recovery of head and trunk movements are key to the achievement of sitting balance. It was evident that there was an overlap in the issues raised by the methods of assessment of sitting balance (including trunk control) and those used to measure head activity. The measurement of sitting balance following stroke is therefore critically reviewed first, followed by the assessment of head activity.

1.3.1 Measurement of sitting balance following stroke

The achievement of sitting balance is routinely measured in patients following stroke. Major differences, however, exist in the available assessment methods. Variables include: the amount of support for the patient, the duration for which sitting balance is maintained, whether measurement is of static and/or dynamic sitting balance, and whether quality of the position is defined. Some measures of sitting balance form parts of larger motor assessment scales, while others stand alone. Table 1.1 details each of the above-mentioned variables for methods of assessment of sitting balance identified in the literature.

Support	Duration	Static or dynamic	Quality defined	Part of larger scale	Reference
Feet on floor Hands in lap	15 seconds	Both	No	No	Sandin and Smith 1990
Feet on floor Upper limbs not defined	10 seconds	Both	Yes – rated separately	Yes Item 3 of 9 item tool	Motor Assessment Scale Carr and Shepherd (1985)
Feet on floor Hands in lap	One minute	Static	Yes – not rated separately	Yes Item 1 of 4 item tool	Mobility Milestones Smith and Baer (1999)
Feet on floor Upper limbs not defined	One minute	Static	No	No	Partridge (1987)
Feet unsupported No arm support	Not defined	Static	No	No	Bohanon (1986)
Feet on floor Upper limbs not defined	Not defined	Both	No	No	Feigin et al. (1996)
Feet unsupported No arm support	Not defined	Static	No	Yes – item 1 of 13 item scale	Rivermead Motor Assessment Lincoln and Leadbitter (1979)
Feet on floor Arms folded across chest	10 seconds – 2 minutes	Static	No	Yes – Item 3 of 14 item scale	Berg Balance Scale Berg et al. (1989)
Feet on floor Upper limbs not defined	30 seconds	Static	Yes – rated separately	Yes – Item 4 on 4 item scale	Trunk Control Test Collin and Wade (1990)
Feet on floor Arms in lap	10 seconds	Both	Yes – rated separately in dynamic sitting	Yes – Part of tool to assess trunk motor impairment	Trunk Impairment Scale (TIS) Verheyden et al. (2004)
Feet on floor Upper limbs not defined	Not defined	Static	Yes	No	Taylor et al. (1994)
Feet on floor Upper limbs not defined	10 seconds – 5 minutes	Static	No	Yes – part of tool to assess postural control in sitting and standing	Postural Assessment Stroke (PASS) Benaim et al. (1999)
Feet on floor Upper limbs used for support	30 seconds	Static	No	Yes – part of tool to assess balance disability	The Brunel Balance Assessment Tyson and DeSouza (2004)
Feet on floor No upper limb support	3 arm lifts in 15 seconds	Static +	No		
Feet on floor No upper limb support	Not specified	Dynamic (Forward reach)	No		

Table 1.1 Methods of measurement of sitting balance following stroke

With the definitions of sitting balance being dependent on the method of assessment used, it is possible for subjects to be rated as achieving independent sitting balance using one method but not with another. As a result any generalisations that can be drawn from the studies investigating sitting balance as a predictor of outcome (see Section 1.1.5.e) have been compromised. Measurement and retraining of sitting balance is commonly used in the early rehabilitation of patients with acute stroke. For sitting balance is to be used effectively as a measure of the efficacy of any early intervention, a universally accepted standardised measure is required.

The Brunel Balance Assessment (Tyson and DeSouza, 2004) was developed specifically with the aim of assessing the effectiveness of stroke physiotherapy interventions. The first three items of the 12-item scale rate the ability of a subject to perform a series of progressively demanding balance tasks within the seated position. The three items form a hierarchy of rating sitting balance, from supported static sitting (where the subject uses his or her upper limbs for support), to sitting with upper limb activity (raising unaffected arm), to dynamic sitting (where the subject performs a seated forward reach of at least 11 cm). However, the tool does not rate any component of the quality of movement performed.

Continuing work in the development of new methods of assessing sitting balance that include quality components (e.g. Taylor et al. 1994; Verheyden et al. 2004), can be seen to reflect the limitations of the measures currently available.

Taylor et al. (1994) looked at the relationship between symmetry of seated trunk posture with motor function and unilateral neglect in 38 patients with acute stroke (see Section 1.2.3.c). Trunk posture was rated by live postural observation using a four-point assessment scale. The trunk position was rated as: midline, to the affected side, to the unaffected side, or unable to sit. At six weeks following stroke all but one patient was able to sit independently. However, a significant difference in gross functional outcome was found between those leaning to their affected side, and those either upright or leaning to their unaffected side. It is apparent that these differences would not have been detected without the measure of quality of posture.

A particularly interesting feature of work the work by Taylor et al. (1994) is the rating of quality of position and/or movement, separate from achievement of the task. Patients who could sit independently and symmetrically were scored differently to those who sat asymmetrically, *and* those unable to sit. This is in contrast with the method used to measure sitting balance in the mobility milestones (Smith and Baer, 1999). Using the mobility milestones it is not evident whether a failure to achieve sitting balance is as a result of the patient requiring support, or because of asymmetry of posture. The development of tools separately rating quality of position or movement and goal achievement are arguably most likely to reflect the goals of early therapy and be sensitive to change.

Verheyden et al. (2004) describe the development of a new tool, the Trunk Impairment Scale (TIS), to measure motor impairment of the trunk in sitting following stroke. Underpinning the development of the TIS is a belief in the importance of measuring quality of movement and not just task achievement. The TIS is the result of further development of a tool reported previously (Niewboer, 1995). The TIS is a live-rated observational tool consisting of three subscales: static sitting balance, dynamic sitting balance, and trunk coordination, and includes observation of quality of trunk movement. Each subscale contains between 3–10 items, and total score ranges from 0–23. In the static sitting balance section subjects are rated on their ability to sit and to sit cross-legged. Quality of cross-legged sitting position is rated. In the dynamic sitting balance section subjects are rated on their ability and quality of movement when leaning to each side, and when lifting the pelvis on each side. In the coordination section subjects are rated on their ability and quality of upper and lower trunk rotation. Early reports of inter-rater reliability were promising, and validity testing is ongoing. It is of interest why the trunk 'activities' assessed on the TIS are not assessed during functional activities. With one of the aims of the TIS stated as being 'a guide for treatment', and with the increasing emphasis on, and evidence to support, task-related training following stroke, whether the choice of a non-functional assessment method was most appropriate is debatable.

1.3.2 Limitations of the tools used to assess sitting balance

To date the terminology used in the methods available for the assessment of sitting balance following stroke is inconsistent. As a result no standardised definition of what constitutes 'independent sitting balance' exists. The majority of assessments are of task achievement with quality of the sitting position achieved, or the ability to move within the position less frequently assessed. In the assessment methods where quality of position is rated, a distinction is not always made between a failure to achieve sitting balance due to an inability to sit, or as a result of not meeting the definition of quality. Assessments tend to be of static stability and not dynamic stability, meaning that information regarding the ability of the patient to transfer his or her weight within the base of support and control the movement of body segments is missed. The majority of assessments of sitting balance have not been tested for external criterion validity or construct validity.

1.3.3 Measurement of head activity following stroke

To date no comprehensive clinical method of measuring head activity following stroke has been reported. Methods using non-clinical tools (Campbell et al., 2001; Brady and Mackenzie, 1999), or part of a clinical tool under development (Carr et al., 1994; 1999), have however, been reported. In the next section the merits and weaknesses of these methods will be discussed. The key features of the method of measuring head activity used by each assessment are summarised in Table 1.2.

Reference	Method of measurement	Merits of the measurement method	Weaknesses of the measurement method
Campbell et al. (2001)	CODA used to measure head and trunk movements during a seated lateral reach.	3-dimensional Light weight markers	Laboratory based Complex marker placement. Three markers were placed on the face Variability of marker placement raised as limitation by authors.
Brady and Mackenzie (1999)	Categorical rating from video recordings of gesture type used during conversation	Subjects do not have to "wear" equipment Suitable for the acute clinical setting. Presence of video camera may impede natural movement.	Validity and reliability of rating gesture from video recordings not established
Carr et al.(1999)	Live categorical rating of head, trunk, and limb positions in sitting and lying.	Subjects do not have to "wear" equipment. Suitable for the acute clinical setting.	External validity not established. Poor inter-rater agreement for many of the categories.

Table 1.2 Methods of measurement of head activity

Campbell et al. (2001)

The findings of the study by Campbell et al. (2001) have been discussed previously (see Section 1.2.3.d). The authors used a laboratory-based 3-dimensional computerised movement analysis system (CODA) to measure head activity during a seated lateral reaching task. To measure head activity three markers were placed on the face (the lower border of the non-dominant eye socket in line with the meatus of the ear; the mid point of the forehead; and the chin). For the trunk, markers were placed on both acromioclavicular joints, and both superior iliac spines. A wealth of data was collected by CODA, but the laboratory-based equipment used introduced several limitations to the study. The location of data collection in a non-clinical area, and the lengthy equipment set-up time, is likely to have limited the severity and number of patients recruited. The influence of assessment fatigue on the patient's movement performance, and the wearing of equipment (particularly on the face), needs to be considered. Certainly, the marker placements used by Campbell et al. (2001) would limit the type of head activity that could be measured.

Brady and Mackenzie (1999)

Brady and Mackenzie (1999) investigated the gesture use of ten patients at one and six months following acute right hemisphere stroke. The patient's use of gesture during discourse was recorded during an interview with the researcher who sat directly opposite the patient. Gesture use was analysed from video recordings using both modality and functional categories (Wallbott 1995). The 'modality' categories describe gestures in terms of the body part being used, (e.g. used head, hand, digit, body, and facial movement), while the 'functional' classification describes gestures in communicative terms (e.g. baton, ideograph, deictic, kinetograph, and pictograph). The authors stressed the need to use a method of rating head movement that did not require equipment to be worn on the head. Unfortunately validity and reliability data for the rating categories were not presented.

Carr et al. (1994; 1999)

Carr et al. (1994; 1999) describe the development of a clinical tool to rate the lying and sitting postures of patients with stroke. Postures were rated live and not recorded by photograph or video. For the seated position head posture was described in terms of: the degree of cervical lateral flexion, rated on a six-point scale, the degree of rotation, rated on a six-point scale, and the degree of flexion, rated on a five-point scale. In addition the degree of trunk lateral flexion and rotation were both recorded on four-point scales. All scales were presented pictorially. The method used by Carr et al. (1994; 1999) had the benefit of not requiring specialised equipment, and being suitable for use in the acute clinical setting. Unfortunately the inter-rater reliability of the tool was only poor to fair, and external criterion validity was not reported. The development of a live-rated tool to describe the posture of patients with stroke would have merit; however, the tool must be valid to be of use.

These studies highlight the methodological issues encountered when measuring head activity, which are exacerbated by the acute clinical condition of the subject group under investigation. To date the measurement of head activity in patients following stroke has been non-clinical, or has formed part of a larger clinical tool for which the measurement emphasis was not head activity (Carr et al. 1985; Stone et al. 1991). A simple, valid, and reliable clinical tool to rate head activity is yet to be developed.

1.3.4 Limitations of published methods of measuring head activity following stroke

The lack of published work on methods of measurement of head activity following stroke is the major limitation. None of the methods of measurement of head activity reported were suitable for use in the acute clinical setting. All three studies identified looked only at a single aspect of head activity using a single task (static posture, communication, lateral reach), and measured head activity as part of a measurement of other body part positions and/or movements, i.e. the focus of the measurement method used was not head activity. Neither of the methods used by Carr et al. (1994; 1999) or Brady and Mackenzie (1999) had established criterion validity or acceptable levels of reliability.

1.4 Need for further research

Following a review of the work undertaken to date investigating head activity following stroke, gaps in the knowledge base have been identified. Abnormalities of head activity have been subjectively reported for several decades by both physiotherapy pioneers (e.g. Bobath, 1990; Davies, 1990; Carr and Shepherd, 1998) and more recently by surveys of practising clinicians (Chatterton et al., 2001), and via modified focus groups (Tyson and De Souza, 2003). However, despite the apparent acknowledgement of the importance of head activity in postural control and recovery following stroke, only very limited evidence exists as to the actual abnormalities of head activity that present following stroke. No clinical method of measuring and describing head activity following stroke has been reported. As a consequence, a comprehensive description of the abnormalities of head activity seen following stroke is lacking. This is true for all stages of the recovery process, from the early manifestation of abnormal head activity in the acute phase of rehabilitation, to any long-term consequences of abnormal head activity that may develop. How head activity changes with recovery from stroke remains un-researched. Whether different patterns of recovery of head activity are seen depending on type and severity of stroke is not known. Fundamentally, the question of whether abnormalities of head activity impact on functional outcome following stroke is yet to be answered. Running parallel to the gaps in knowledge of head activity at the activity level (interaction of the individual with the environment) and participation level (within the individuals in social context) are gaps at the impairment level (signs and symptoms of a deficit in body structure or function) as described by the International Classification of Functioning, Disability and Health (ICF) (WHO, 2001). Knowledge of the mechanisms that underpin abnormalities of head activity following stroke, particularly the coordination of head–eye movements during body movements, is required to understand the effect of different types and level of severity of stroke on head activity. In addition, a better theoretical understanding of the underlying mechanisms of disordered eye, head, and trunk movement coordination is needed for the development of effective treatment strategies aimed at improving the functional outcome of patients with abnormalities of head activity. In summarising the gaps in knowledge at the present time, it is apparent that several areas of investigation into the abnormalities following stroke need to be pursued. However, a necessary first step to understanding the abnormalities of head activity following stroke at any level (impairment, activity or participation) is a description of the head activity demonstrated by patients. In order to meet this need, the head activity used during a variety of tasks, with different challenges presented by each task reflecting the different roles of head activity, needs to be described.

1.4.1 Hypotheses to be tested in this thesis

The hypotheses to be tested in the thesis directly reflect the gaps in knowledge identified in the literature review. In order to describe the head activity demonstrated by patients following stroke a suitable assessment tool is required. A need has been identified for an assessment tool that provides a comprehensive record of head activity, which is sensitive to change over time. The first part of the work presented in this thesis (chapters 2 and 3) will describe the development of an assessment tool to meet this need. Only with the development of such an assessment tool can the following study hypotheses be either supported or refuted.

- **Impaired head activity is a frequent early consequence of stroke and patients demonstrate abnormalities of head activity during simple seated functional tasks.**

- **The level of head activity demonstrated by patients is correlated with type of stroke, motor impairment, balance impairment, and level of function.**

- **Those with poor head activity in the first week following stroke have lower functional outcome at six weeks than those with good initial head activity.**

These hypotheses will be tested using the new assessment tool in the subsequent chapter (Chapter 4). In Chapter 5, a more detailed description of head activity provided by three-dimensional motion analysis, further testing the first hypothesis, is reported.

Chapter 2
Design of a tool to assess head activity following acute stroke

2.1 Introduction

The literature review outlined in Chapter 1 failed to identify a suitable tool with which to assess the head activity of patients following stroke. To address this omission a new head activity assessment tool was developed.

In the development of a new assessment tool the population for whom the tool is targeted should guide the selection of the tool's components. The target population for the new assessment tool to measure head activity was patients with acute stroke, many of whom have severe motor and balance impairments, and have difficulty standing and walking independently.

The use of standardised tasks provides a means of determining the roles of head activity that can be assessed. A single role may be assessed by one task, while different roles may require multiple tasks. In the assessment of head activity following acute stroke, the assessment tasks must be suitable for use in the clinical setting, with consideration given both to time required to complete the tasks, and to their complexity.

Having established the standardised tasks, the means of describing the head activity demonstrated must be determined. In the development of a new assessment tool Streiner and Norman (2000) describe five sources from which tool items can be obtained: the subjects or patients, clinical observations, theory, research, and expert opinion; however, the authors highlight that the boundaries between the sources are not firm. Gathering tool items from a broad range of relevant sources ensures their face validity.

With the tool items identified, a method of rating the items is required. As the tool to assess head activity will initially be video-based, the proposed method of rating must be appropriate for the analysis of movement from video recordings.

2.1.1 Aim

To develop a tool to assess the head activity of people following acute stroke

2.2 Designing the Head Activity Test (HAT)

The absence of a tool to assess head activity identified in the literature review meant that a new assessment tool needed to be developed in order to address the hypotheses stated in Section 1.4. To ensure the methodological strength of the tool, and its suitability for use in the acute clinical setting, the following criteria were set as tool requirements:

i. To have face validity
ii. To have content validity
iii. To be user friendly
iv. To demonstrate external criterion validity
v. To achieve acceptable levels of inter-rater and intra-rater reliability

Criteria i-iii (the early development of the head activity assessment tool) will be addressed in this chapter. Criterion iv will be addressed in Chapter 3A, and criterion v in Chapter 3B.

The early development of the head activity test comprised four stages:

Phase 1: To identify the components of the assessment tool i.e. the assessment tasks
Phase 2: To identify descriptors of head activity
Phase 3: To shortlist the measurable head activity descriptors for use as tool items.
Phase 4: To identify a method of scoring the tool items
A flow diagram of the methodological processes used in the development of the tool. is illustrated in figure 2.1.

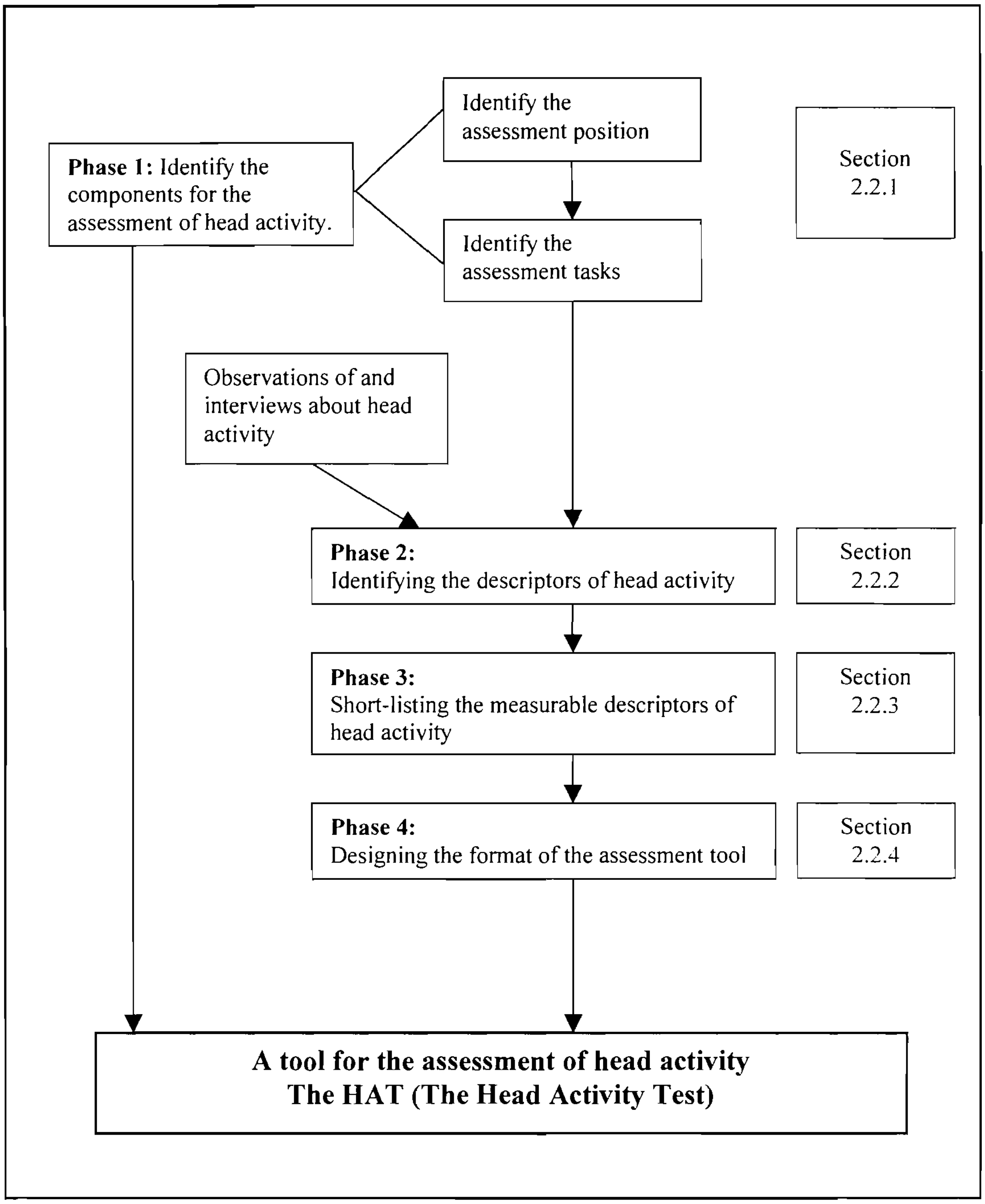

Figure 2.1 Tool development process

2.2.1 Phase 1: Identifying the components for the assessment of head activity

In order to identify the components of the assessment of head activity the following questions needed to be answered: what position should the subject be in during assessment of head activity? What should the subject be doing?

Objective: To identify the position of the subject and the tasks to be undertaken during assessment of head activity

2.2.1.a Method

A literature search was undertaken to identify the methods currently used in the assessment and the treatment of head activity following stroke. Assessment and treatment methods were included if they met the following criteria:

- The task was **simple** to carry out, without the need for complex instruction requiring high levels of cognitive processing.
- The task was an **everyday functional task**, or represented an everyday functional goal of head activity.
- Each task had a **single primary goal** of head movement.

The methods identified in the literature were categorised into their component parts: i) the position of the patient, and (ii) the assessment or treatment task.

2.2.1.b Procedure

A broad literature search was undertaken using the key words: *stroke, head movement, head position, head activity, balance, postural control, assessment, and measurement.* Head activity assessment and treatment methods were identified from research articles, review articles, books, and published measurement tools. Once identified, the assessment and treatment methods were checked against the task criteria and tabulated, categorising the position of the patient, and the task being carried out. The components identified were then modified to form the component parts of the head activity assessment tool under development. Expert opinion was used in the process of finalising the new tool's components.

2.2.1.c Results

Nine methods of assessment or treatment of head activity of patients with acute stroke, which met the task criteria, were identified in the literature. The tasks and the positions, involved in treatment and assessment methods are shown in table 2.1.

Method of assessment or treatment	Reference	Component parts	
		Task	Position
Assessment of trunk alignment in sitting.	Taylor et al. (1994)	Upright sitting	Unsupported sitting
Development of an assessment tool for rating sitting position including head position.	Carr et al. (1999)	Upright sitting	Supported sitting
Development of an assessment tool for rating sitting balance including head position.	Nieuwboer et al. (1995)	Upright sitting	Unsupported sitting
A modified version of The Behavioural Inattention Test (Wilson et al., 1987) for the use with patients with stroke includes a test where patients are required to visually locate objects about the ward.	Stone et al. (1991)	Visual search	Supported sitting
A scanning and trunk rotation task as intervention for unilateral neglect using the Bon Saint Come device.	Wiart et al. (1997)	Visual search task	Unsupported sitting and standing
As part of Motor Assessment Scale (MAS) the ability to "sit unsupported and turn head and trunk to look behind" is rated.	Carr et al. (1985)	Visual search	Unsupported sitting
Assessment of gesture use including use of the head for gesturing during conversation by patients with stroke.	Blonder et al. (1994) Brady and MacKenzie (1999)	Communication	Supported sitting
The effects of various head and neck positions on swallowing were investigated in patients following stroke.	Logemann et al. (1994); Castell et al. (1993) ; Ertekin et al. (2000)	Eating/drinking	Supported sitting
Investigated head and trunk movement strategies used by patients with stroke during a dynamic lateral reach.	Campbell et al. (2002)	Reaching	Unsupported sitting

Table 2.1 Head activity component parts

The expert opinion used in the process of finalising the head activity assessment tool's components was comprised of five researchers: a research bioengineer, an occupational therapy researcher, and three physiotherapy researchers. Each researcher had experience in the analysis of movement of, and the development of outcome measures for, people with neurological disorders.

2.2.1.c.i Assessment position

From the nine methods of assessment and treatment of head activity presented in the literature, three positions were identified: (1) supported sitting (sitting in wheelchair), (2) unsupported sitting (sitting on a plinth with feet flat on the floor), and (3) standing (see table 2.1). Five methods used unsupported sitting, and four used supported sitting. One method used both unsupported sitting and standing. Unsupported sitting was agreed, by consensus of the expert group, to be the position of the patient for the assessment tool under development.

2.2.1.c.ii Assessment tasks

Only five tasks were identified from the literature as being components of methods (either under development, or currently being used), in the assessment or treatment of head activity following stroke. The tasks identified were: (1) Upright sitting, (2) Visual search, (3) Communication, (4), Eating, and (5) Reaching. All five tasks were included as components of the assessment tool under development. Elements of the tasks identified in the literature that were appropriate for use in the acute clinical setting were incorporated into the tasks developed for use with the new tool. Table 2.2 summarises each of the five tasks.

Task 1: Upright sitting	Head activity is assessed during quiet upright sitting.
Task 2: Visual Search	Head activity is assessed during a visual search task. The subject is required to search along an eye-level track to both the right and left for a series of lights.
Task 3: Communication	Head activity is assessed during conversation. The interviewer will sit on either side of the subject.
Task 4: Eating	Head activity is assessed whilst subject eats 3 spoons of yoghurt.
Task 5: Reaching	Head activity is assessed during a maximum forward and lateral reaching task.

Table 2.2 Assessment tasks

Upright Sitting

Subjects are instructed to sit as upright as possible, and maintain the position for ten seconds.

Visual Search

The task requires subjects to search and count up to six lights mounted at eye level on a horizontal arc of 240°. The lights are located at 45°, 90°, and 120° to each side. The lights are operated via a control box by the researcher. Subjects are requested to look around and count how many (randomly selected) lights are turned on for each of six search attempts.

Communication

A selection of questions about both recent holidays and holidays experienced as a child was chosen as the basis for the communication task. Head activity is assessed during conversation that arises from a semi-structured interview consisting of both open and closed questions. The interviewer sits on either side of the subject during the communication task.

Eating

Head activity is assessed whilst subjects eat three spoons of yoghurt with a teaspoon. Subjects are instructed to use one hand only.

Reaching

The reaching task comprises a seated forward and seated lateral reach. For both reaches the subjects are instructed to reach as far as they safely can along a height adjusted meter rule whilst maintaining a fixed gaze.

Detailed protocols for each of the tasks are presented in Appendix 1.

2.2.1.d Summary of Phase 1

Head activity will be assessed during five tasks: upright sitting, visual search, communication, eating, and reaching. The tasks chosen capture different roles of head activity. The tasks are simple everyday functional tasks, or component parts there of. The tasks will be carried out in the assessment position of sitting. Sitting was chosen to enable the assessment of patients in the very early stages of recovery following an acute stroke, and to limit the confounding factors on head activity such as changes in base of support, or the requirement for external support. Having identified the components of the Head Activity Test (HAT), the next step in the tool development process was the identification of the descriptors of head activity; this is described in phase 2 of the development process.

2.2.2 Phase 2: Identification of descriptors of head activity

Objective: To identify descriptors of head activity from multiple sources for potential use as tool items. For the purposes of this study a *descriptor of head activity* has been defined as *'terminology used to describe the clinically important aspects of head position or head movement'*. Descriptors of head activity in relation to the trunk, and combined head and trunk activity, are included within this definition. Descriptors were identified from five sources: the literature, clinical practice, experienced therapy clinicians, rehabilitation researchers, and patients with stroke (see figure 2.2).

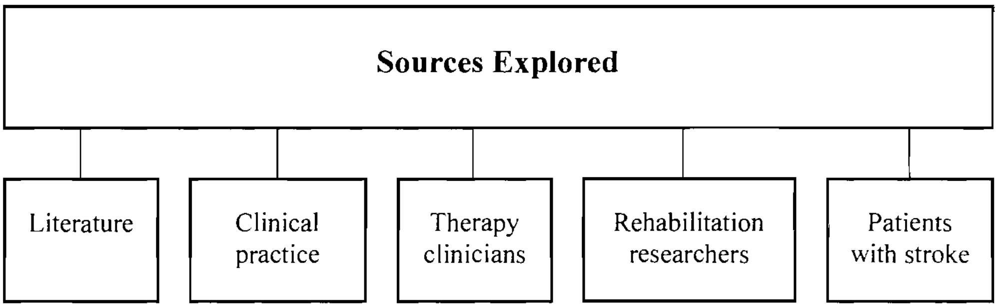

Figure 2.2 Sources from which descriptors were identified

Before the invaluable sources of clinical practice, therapy clinicians, rehabilitation researchers, and patients with stroke could be explored, the means by which each source could contribute to the identification of descriptors of head activity needed to be identified. Video recordings of patients during a physiotherapy treatment session provided the material for the researchers to identify descriptors of head activity from clinical practice. Video recordings of patients and healthy adults carrying out the assessment tasks (identified in phase one) provided the material for descriptors of head activity to be identified from the researcher and clinician sources. Interviews of patients with acute stroke about any change in head activity they had experienced since their stroke provided the method by which the patients' perspective could be incorporated as a source of descriptors. All video recordings and interviews were undertaken in a single study that is detailed in the following section.

An observational study of head activity used by patients with acute stroke and healthy adults

Aim: To provide the data for the identification of descriptors of head activity from the sources of: clinical practice, therapy clinicians, rehabilitation researchers, and patients with stroke.

Method

Following ethical approval from the Local Research Ethics Committee and The Royal Bournemouth and Christchurch Hospitals NHS Trust Research and Development Committee (see Appendix VII a & b), patients with acute stroke and healthy adult controls were recruited into an observational study of head activity. Subjects were recruited from the patients, patients' relatives, and staff of Christchurch Hospital Stroke Unit. Video recordings of subjects were taken. Patients were recorded during a single physiotherapy treatment session and whilst carrying out the assessment tasks identified in phase 1 of the tool development process. The healthy adult controls were recorded whilst carrying out the assessment tasks. In addition, patients were interviewed about their head activity, vision, hearing and dizziness.

Patient Inclusion Criteria: Patients had a diagnosis of first-ever stroke, were medically stable, able to sit supported for 20 minutes, passed a cognitive screening test and able to give informed consent.
Patient Exclusion Criteria: The presence of another neurological condition, history of a previous stroke, vestibular dysfunction or other balance disorder, severe cervical spondylosis or visual impairment not corrected for by glasses.
Healthy adult inclusion criteria: Subjects were aged over 40 years and able to give informed consent.
Healthy adult exclusion criteria: The presence of a neurological condition, vestibular dysfunction or other balance disorder, severe cervical spondylosis or visual impairment not corrected for by glasses.

Procedure

Video recordings of patients during a physiotherapy session were taken at a time convenient to both the patient and the physiotherapists. The content of the physiotherapy session was unaltered, and the whole treatment recorded. The researcher remained in the treatment room during the recording but did not participate in the treatment of the patient. Video recordings of patients and controls carrying out the assessment tasks were taken, and subjects completed each of the tasks following the protocols outlined in Appendix I. Patients were interviewed by the researcher about their head activity and related features using a short, structured interview schedule. The full interview schedule is presented in Appendix IIa (assessment one).

Results

Patient sample

Twenty patients were recorded on video during a physiotherapy session, and carrying out the assessment tasks. All completed the short interview. The sample comprised 11 men and nine women with a median age of 80. Eleven patients had a right hemispheric stroke and nine a left, with a spread of OCSP classification of stroke among the sample. The median time since stroke was two weeks. Basic patient demographic data is presented in table 2.3.

OCSP Classification of stroke (number)		Sex **Number**	Age **Median (range)**	Hemisphere of stroke **Number**	No. of days since stroke on assessment **Median (range)**
TACI (5)	POCI (3)	11 Male	80 (60-94)	11 Right	14 (5-70)
LACI (4)	PACI (5)	9 Female		9 Left	
PICH (3)					

Table 2.3 Patient demographic data

Healthy adult sample

Six healthy adults were recorded on video carrying out the assessment tasks. The sample comprised four women and two men with a median age of 53 (see table 2.4).

Age **Median (range)**	Sex
53 (48-68)	2 Male 4 female

Table 2.4 Demographic data healthy adults

Summary

The observational study of head activity provided the data for the identification of descriptors of head activity from the four sources of: clinical practice, therapy clinicians, rehabilitation researchers, and patients with stroke. Having obtained the video and interview data all five sources of descriptors of head activity could now be explored.

2.2.2.a Method

The data were now available to identify descriptors of head activity from all five sources. The method undertaken to identify the descriptors of head activity varied according to the source being explored. Descriptors of head activity were identified for each of the five assessment tasks separately, and a list relating to each task compiled (see figure 2.3). In view of the exploratory nature of this research, and the paucity of specific head activity descriptors with measurement scores in the literature, all identified descriptors were listed without any measurement value.

2.2.2.a.i Source 1: The literature

Objective: To identify published descriptors of head activity.

A broad literature search was undertaken using the key words: *head position, head posture, head movement, stroke, physiotherapy, measurement, balance, postural control, communication, visual search, eating, and swallowing.* Descriptors of clinically important functional head activity used in sitting were identified from research articles, review articles, books, and published measurement tools. The descriptors of head activity identified were collated and grouped according to the task to which the descriptor pertained. Descriptors used to describe head activity in more than one function were included on all relevant lists. Five lists of descriptors of head activity, one for each of the assessment tasks (sitting, visual search, communication, eating, and reaching) were compiled.

2.2.2.a.ii Source 2: Clinical practice

Objective: To generate descriptors of head activity based on observations of patients with stroke during a physiotherapy treatment session.

A group of therapy researchers experienced in movement analysis were recruited from Southampton University Health and Rehabilitation Research Unit. The researchers were requested to identify descriptors of head activity, and under what circumstance the head activity occurred from the unedited video recordings of the 20 patient physiotherapy treatment sessions. The independently identified descriptors were then collated, and the assessment tasks to which they related agreed by consensus.

2.2.2.a.iii Source 3: Therapy clinicians

Objective: To generate descriptors of head activity from the perspective of practising clinicians.

Therapists experienced in the rehabilitation of people following acute stroke were identified from Southampton General Hospital Rehabilitation Therapy departments. Following therapy managers' consent and the identification of individual therapists experienced in the treatment of stroke patients, the researcher approached the therapists and invited them to take part in the video analysis. The therapists were requested to identify clinically important descriptors of head activity from the video recordings of patients and healthy adult controls carrying out the assessment tasks. The video recordings were edited, removing all data except the assessment tasks, to allow all participants demonstrating the same task to be shown consecutively. Recordings were watched at normal speed, with repeat and slow play viewing used when requested. Each therapist independently identified descriptors of head activity for all five tasks.

2.2.2.a.iv Source 4: Researchers

Objective: To generate descriptors of head activity from the perspective of rehabilitation researchers.

Researchers experienced in movement analysis were recruited from Southampton University Health and Rehabilitation Research Unit. The researchers were requested to identify descriptors of head activity from the video recordings of patients and healthy adult controls carrying out the assessment tasks. The video recordings were edited, removing all data except the assessment tasks, to allow the same task to be shown consecutively. Recordings were watched at normal speed, with repeat and slow play viewing used when requested by the researchers. Each researcher independently identified descriptors of head activity for each of the five tasks.

2.2.2.a.v Source 5: Patients with stroke

Objective: To generate descriptors of head activity from the patients' perception of any difficulties they had experienced with head activity.

All twenty patients were asked a series of questions as part of an interview about the effect of stroke on their head activity and related sensory functions (see Appendix II for the interview schedule). The responses to the following three questions were used as the fifth source of descriptors of head activity.

- **Since your stroke have you had any difficulty moving your head?**
- **Since your stroke have you had any difficulty seeing things around you?**
- **Since your stroke have you had any episodes of dizziness?**

The patient's responses were analysed independently by two researchers. Those identified by either researcher to be descriptive of head activity were listed and grouped. Responses were grouped according to the assessment task to which they best related. Complete agreement between the two researchers was obtained, and the provision made for a third researcher as an arbitrator was not required.

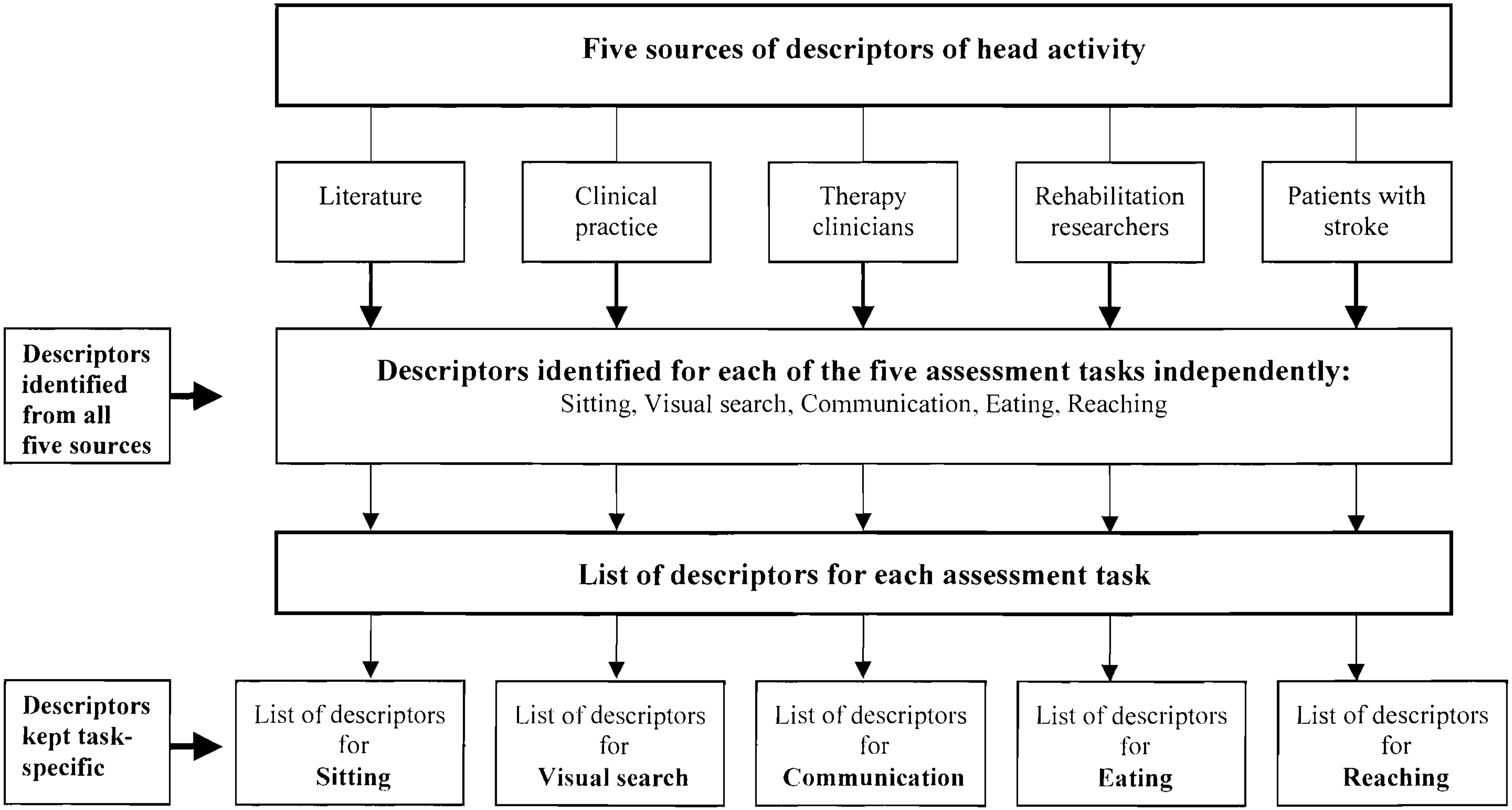

Figure 2.3. Identification of descriptors

2.2.2.b Results

A total of 263 descriptors of head activity were identified from the five sources in phase two of the tool development process (see table 2.5).

Task	Number of categories identified	
Sitting	32	Total sitting = 58
Corrected sitting	26	
Visual search	41	
Eating	34	
Forward reach	36	Total reaching =80
Lateral reach	44	
Communication	52	
TOTAL	= 263	

Table 2.5 Identified descriptors of head activity

2.2.2.b.i Descriptors of head activity identified from the literature

Descriptors: Forty-one descriptors of head activity were identified from the literature in total (see Appendix IIIA): fourteen for sitting, three for visual search, eight for communication, five for eating, five for forward reach, and six for lateral reach.

2.2.2.b.ii Descriptors of head activity identified from clinical practice

Source: Six research therapists were recruited. The group comprised one speech and language therapy researcher, one occupational therapy researcher, and four physiotherapy researchers. Each researcher had at least four years of clinical experience in the treatment of adults with neurological disabilities, and had experience in the analysis of movement using video recordings and categorical rating scales.

Descriptors: Fifty-two descriptors of head activity were identified from clinical practice (see Appendix IIIB): nine for sitting, three for corrected sitting, nine for visual search, twelve for communication, three for eating, eight for forward reach, and eight for lateral reach.

2.2.2.b.iii Descriptors of head activity identified from therapy clinicians

Source: Five senior clinical therapists were recruited. The group comprised one speech and language therapists, one occupational therapist, and three physiotherapists. Each therapist had at least four years clinical experience in the treatment of people with stroke.

Descriptors: Eighty-one descriptors of head activity were identified by clinicians in total (see Appendix IIIC): eleven for sitting, sixteen for corrected sitting, eleven for visual search, sixteen for communication, eleven for eating, seven for forward reach, and nine for lateral reach.

2.2.2.b.iv Descriptors of head activity identified from rehabilitation researchers

Source: Eight researchers experienced in movement analysis were recruited. The group comprised one speech and language therapy researcher, one research biomedical engineer, one occupational therapy researcher, one research nurse, and four physiotherapy researchers.

Descriptors: Eighty-five descriptors of head activity were identified by researchers in total (see Appendix IIID): three for sitting, seven for corrected sitting, seventeen for visual search, sixteen for communication, fifteen for eating, sixteen for forward reach, and twenty-one for lateral reach.

2.2.2.b.v Descriptors of head activity identified from patients with stroke

Source: All 20 subjects responded to the interview questions.

Descriptors: The researchers independently identified two distinct groups of responses, one related to head position and postural control, and one of vision dependent head activity. The descriptions that included any reference to vision were grouped under the visual search task and all others in the sitting task. Agreement was reached between the researchers as to the responses, and their wording, that were to be included as descriptors.

The following are examples of patient's responses included as descriptors of head activity:

Since your stroke have you had any episodes of dizziness?

- "I tend to lean one way".

Included as the descriptor: 'Leaning one way' for the upright sitting task.

- "Not dizziness but feel off balance".

Included as the descriptor: 'Off balance' for the upright sitting task.

Since your stroke have you had any difficulty seeing things around you?

- "You look at things and then they've gone, so you need to look again".

Included as the descriptor: 'Repeated searches for individual targets' for the visual search task.

Seven descriptors of head activity were identified from the patients' interview responses (see Appendix IIIE): five for sitting, and two for visual search. No descriptors were identified for communication, eating, or reaching.

2.2.2.c Summary of Phase 2

Descriptors of clinically important functional head activity were identified from five sources: the literature, clinical practice, therapists, researchers and patients.
The literature was systematically searched through databases and key words. Video recordings of patients with acute stroke during physiotherapy sessions were used in the identification of descriptors from clinical experience. Recordings of patients and controls carrying out the assessment tasks were used in the identification of descriptors by researchers and clinicians. The patients' perspective was obtained through interview. The lists of descriptors of head activity identified from each of the five sources were collated for each task. A total of 263 descriptors of head activity were identified in phase two. This long list of descriptors provided the pool of potential tool items for grouping and short-listing in the next phase of the tool development process.

2.2.3 Phase 3: Short-listing the descriptors to form tool items

Objective: To reduce the 263 descriptors of head activity identified from the five sources in phase two to a manageable number of tool items.

2.2.3.a Method

The 263 identified descriptors of head activity were short-listed in a two-stage process.

Stage 1

Two researchers independently grouped the descriptors of head activity according to themes for each of the assessment tasks. No limitations were set regarding the number of themes or the number of descriptors within each theme. The themes were compared and agreement reached on the final groupings of descriptors for each task. Provision was made for a third researcher to act as an arbitrator, but this was not required.

Stage 2

A group of eight researchers (all of whom had been involved in the tool development process at an earlier stage) was presented with the descriptor themes for each task. The group re-watched the video recordings and through group discussion agreement was reached as to which descriptors were measurable. The measurable descriptors were then defined to form tool items.

2.2.3.b Results

Stage 1

Twenty themes of head activity were identified in total, five for upright sitting, three for visual search, five for communication, three for eating, and two for each of the reaching tasks.

Stage 2

From the twenty themes of head activity ten measurable descriptors were identified. The ten measurable descriptors were defined to form tool items, four for the upright sitting task, two for the visual search and communication tasks, and one for the eating and reaching tasks.

Figures 2.4-2.8 diagrammatically illustrate the results of short-listing the descriptors into themes, and identifying measurable descriptors to form tool items.

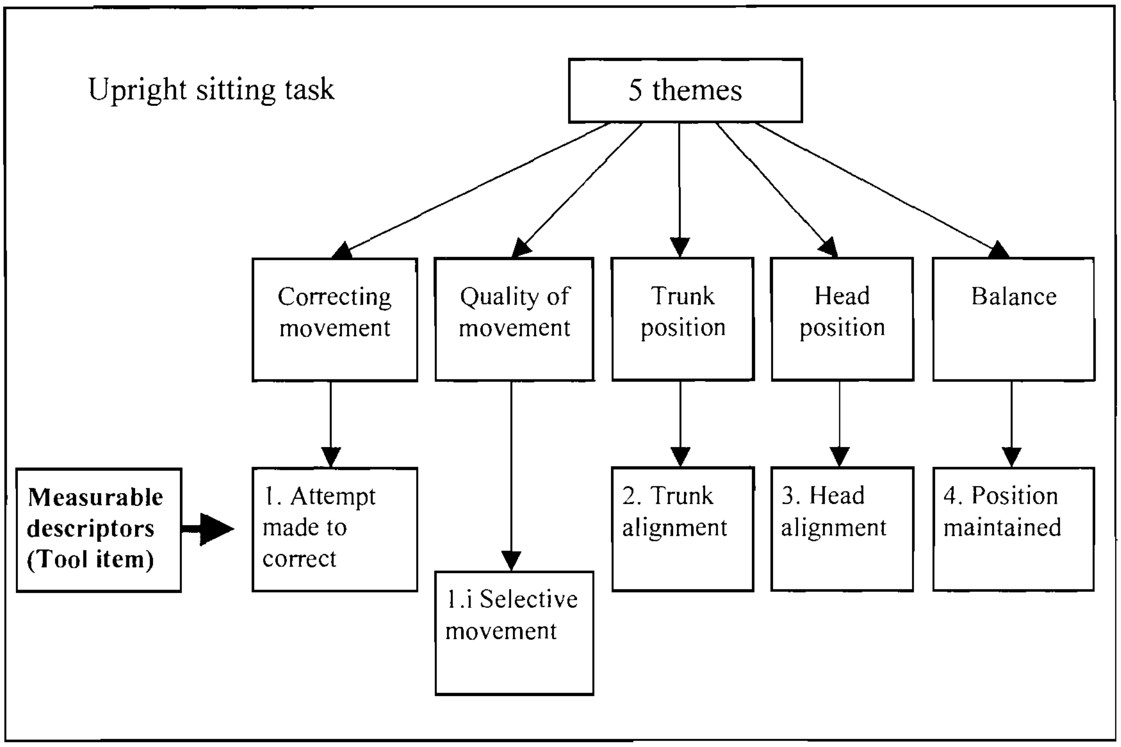

Figure 2.4. Short-listing descriptors for the upright sitting task

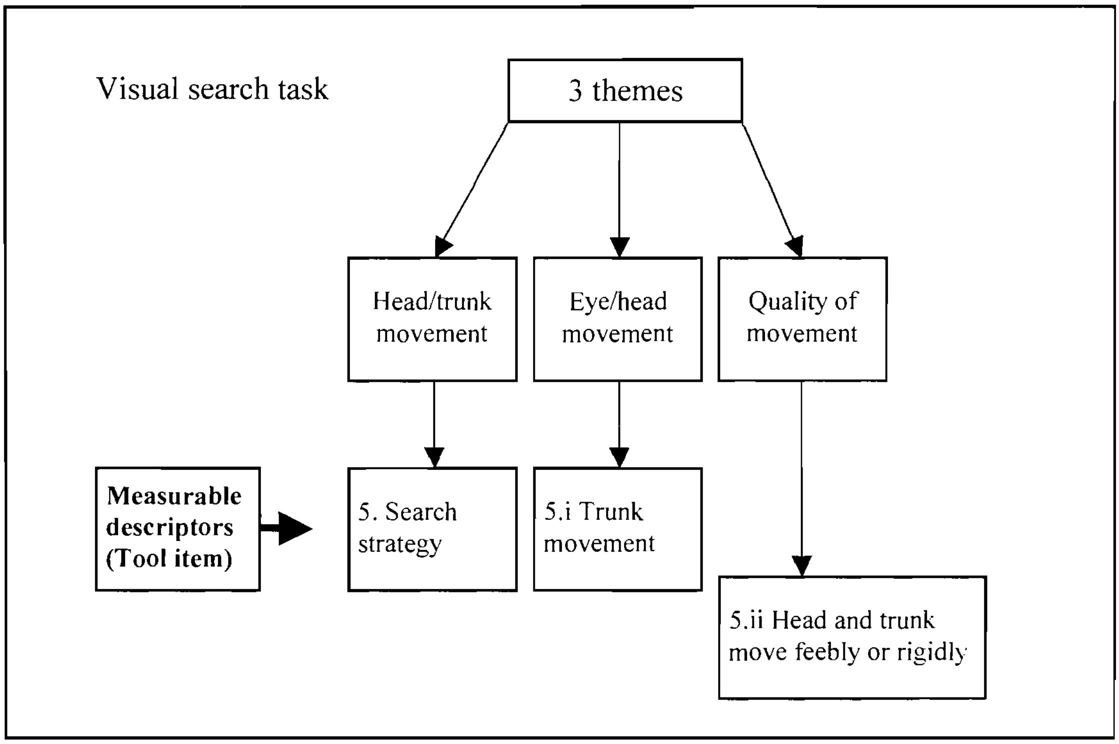

Figure 2.5 Short-listing descriptors for the visual search task

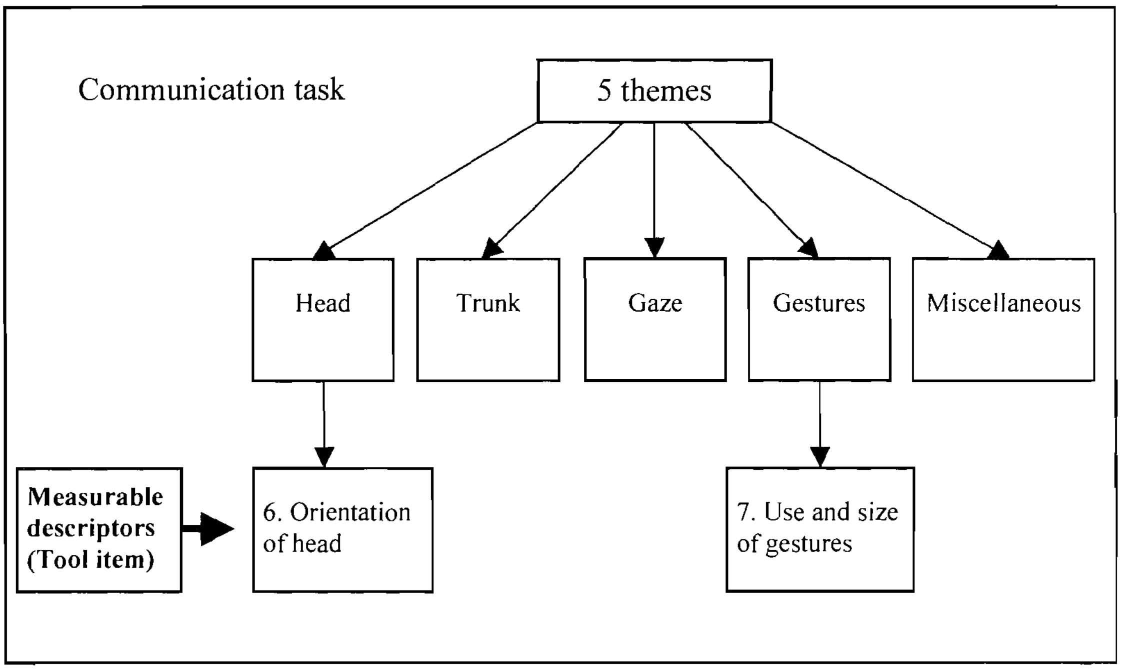

Figure 2.6 Short-listing descriptors for the communication task

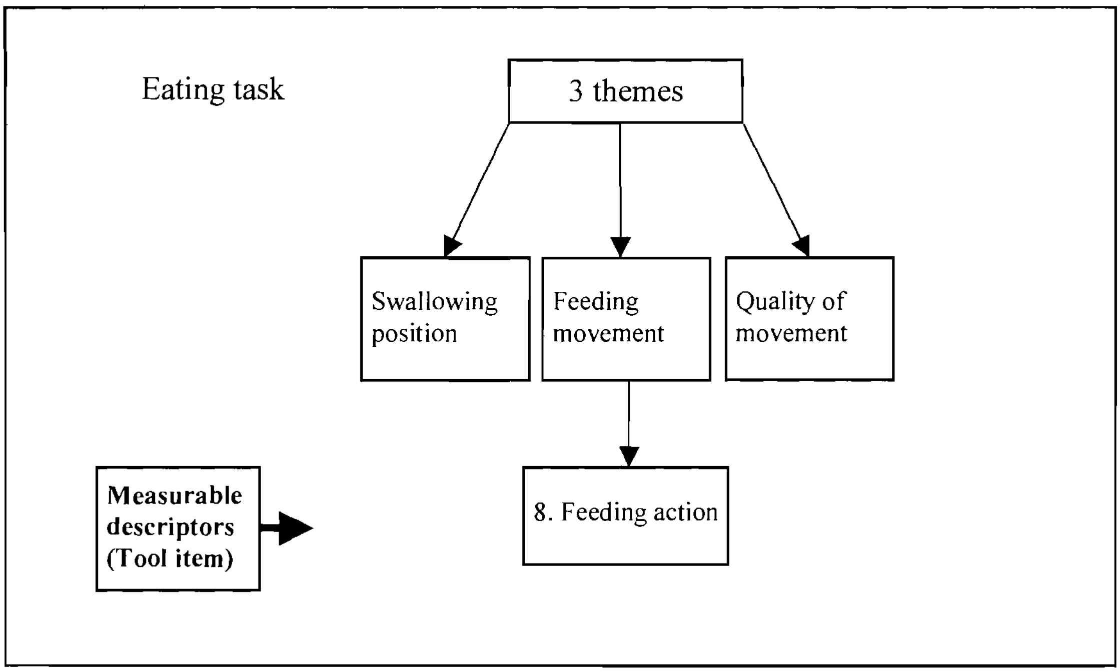

Figure 2.7 Short-listing descriptors for the eating task

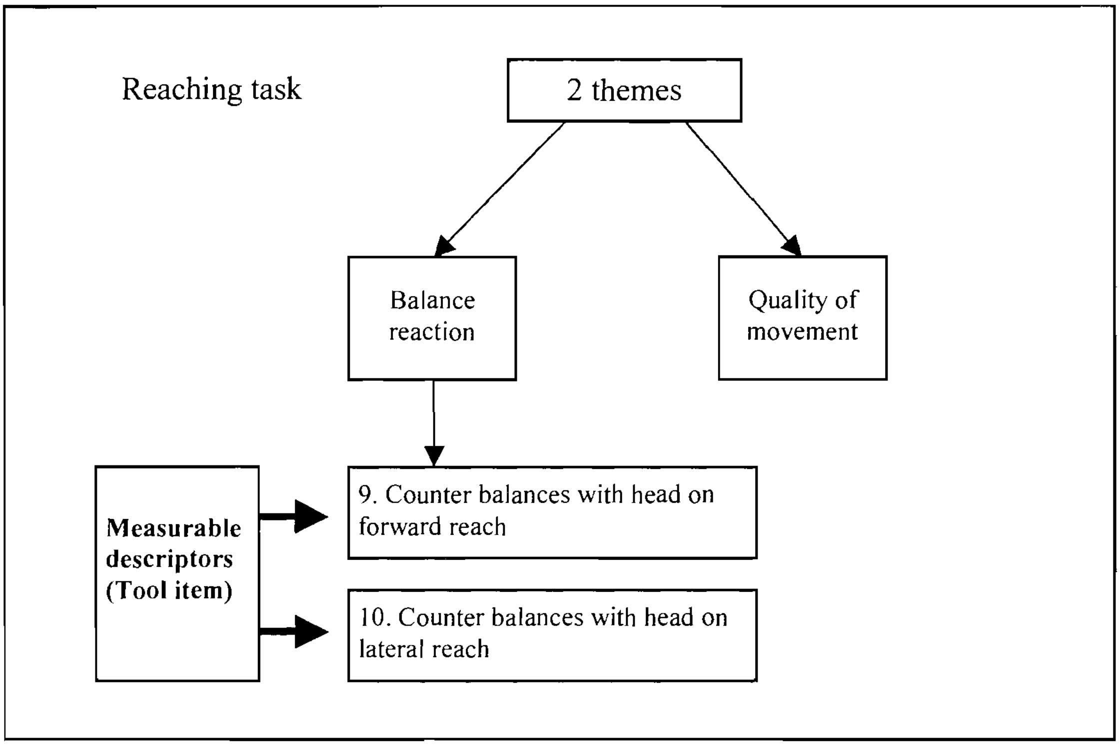

Figure 2.8 Short-listing descriptors for the reaching task

2.2.3.c Summary of phase 3

A two stage short-listing process reduced the 263 identified descriptors of head activity to ten measurable tool items. At least one tool item was identified for each of the five assessment tasks. Having defined the tool items, the next stage in the tool development process was to establish the method of scoring the tool items, and to design the format of the assessment tool.

2.2.4 Phase 4: Designing the assessment tool

Objectives: To establish the method of scoring the tool items describing head activity, and to design a user-friendly assessment tool.

2.2.4.a Method

2.2.4.a.i Method of scoring

A group of eight researchers (the same group as participated in the short listing of the descriptors) was presented with the tool items identified for each task. Through group discussion, consensus was reached on the measurement method, and score value for each of the ten tool items.

2.2.4.a.ii Design of the tool

A simple, easy to use format was designed that required minimal response time and effort from the rater. Instructions for the tool's use were developed and incorporated onto a separate form with definitions of all the terms used (see Appendix IV). Feedback regarding the usability of the assessment tool and the guidelines for its use was sought from three researchers and three clinicians, who had not previously seen the tool. The feedback was acted upon and amendments to the tool layout and the terminology used were made.

2.2.4.b Results

2.2.4.b.i Method of scoring

It was agreed by consensus that all the tool items should be rated categorically. A simple scoring system was devised with the majority of tool items being scored as 1 (YES) or 0 (NO). Descriptive sub-items are not scored. The measurement method and scoring system for the tool items are outlined below for each task is in turn.

Upright sitting task

For upright sitting, whether the subjects attempt to correct their sitting, whether they use selective movement to do so, whether they achieve an upright trunk and head position and whether they maintain the position are all scored as yes or no. If upright head position is not achieved, head position is recorded on a six point scale: protracted, flexed, rotated to the right or left, or side-flexed to the right or left.

Visual search task

For the visual search task, the search strategy used by the subject is recorded on a three-point scale describing the amount of head movement used to search. Whether the subjects use their trunk is recorded as yes or no, and if yes, the quality of this movement is recorded as either free or rigid.

Communication task

For the communication task the orientation of the subject's face relative to the interviewer is recorded on a three-point scale. The use of the head for gesturing is recorded as yes or no. Gestures size and frequency is recorded on a three-point scale.

Eating task

For the eating task the feeding action is rated on a three-point scale describing the contribution of head movement to the coordinated action of spoon to mouth.

Reaching task

For each of the forward and lateral reaching tasks, whether the subject demonstrates a counterbalancing movement with the head is recorded as yes or no.

As each task does not have the same number of scored tool items, the tasks do not contribute equally to the total HAT score. However, multiplying the number of themes by the number of descriptors for each task gives a rank order the same as that for the scores for each task (see table 2.6).

	No. of descriptors	No. of themes	Number of items scored	Rank order (categories x themes)	Rank order of score
Upright sitting	58	5	4	1	1
Visual Search	41	5	1	4	4=
Communication	52	3	2	2	2=
Eating	34	3	1	5	4=
Reaching	80	2	2	3	2=

Table 2.6 HAT task score contribution

The total score for the HAT is the sum of the tool item scores giving a maximum score of ten. Patients unable to sit independently are given a total score of zero, but are not rated or scored on individual tasks.

2.2.4.b.ii Design of the tool

A ten-item categorical tool, the Head Activity Test, the HAT, was developed (see figure 2.9). The HAT consists of easy-to-read tick-box responses set out in five distinct sections, one relating to each task. The ten tool items require eighteen ratings to be made in total. Items 7, 8 and 8.i are rated twice (while the subject carries out the task with the interviewer sitting on either side). Items 1, 3, 5, and 7, have a sub-category each, the rating of which is dependent on the rating of the tool item to which it corresponds. The definitions of terms and guidelines for the use of the tool are set out in Appendix IV.

2.2.5. Summary of phase 4

The **Head Activity Test (HAT)** has been developed for the measurement of the head activity following acute stroke. The HAT consists of ten categorically rated tool items to score the head activity demonstrated during five seated functional tasks.

Upright Sitting

ID No.

	1. Attempt made to correct	Yes	No	Score 1 if yes to both
If	Selective movement	Yes	No	

Sitting position

2. Trunk upright	Yes	No	Score 1 if yes
3. Head upright	Yes	No	Score 1 if yes

If No

Flexion
Protraction/extension
Right Side flexion
Left Side flexion
Right Rotation
Left Rotation

If upright trunk and head

4. Maintained	Yes	No	N/A	Score 1 if yes

Visual Search

5. Search Strategy	Head moves both ways		
	Head moves one way	**Right**	**Left**
	Incomplete search		

Score 1 if head moves both ways

Trunk Movement	No		
			Head and trunk rigid
	Yes	**If Yes**	
			Head and trunk move freely

Communication

6. Orientation of head	**Right**	**Left**
Away from interviewer		
Towards interviewer		
Varied head positions including towards		

Score 1 if Towards or Varied R **and** L

7. Uses head for gestures	**Right**	Yes	No
	Left	Yes	No

Score 1 if Yes R **and** L

If Yes

Frequent and large	**R**	**L**
Moderate	**R**	**L**
Minimal and small	**R**	**L**

Eating

8. Feeding action	Arm only	Score 1 if meet in the middle
	Head to pot	
	Meet in the middle	

Reaching

9. Counter balances with head	Forward reach	Yes	No	Score 1 if yes
10. Counter balances with head	Lateral reach	Yes	No	Score 1 if yes

HAT Score

Upright sitting	/4
Visual search	/1
Communication	/2
Eating	/1
Reaching	/2
Total Score	**/10**

Figure 2.9 The HAT

2.3 Discussion

The literature search revealed an absence of a tool to describe the head activity following stroke that was suitable for use in the clinical setting. A simple protocol is required to test and evaluate performance in order not only to describe head activity, but also to facilitate appropriate research (including the development of interventions), and communicate findings. To meet this requirement, a new tool, the HAT, was developed. The exploratory work undertaken in the development of the HAT represents new work in the area of analysis of movement used by people following stroke. In the following sections each of the four phases of the development process is discussed in turn.

2.3.1 Phase 1: Identification of the components for the assessment of head activity

One consequence of the absence of an appropriate assessment tool has been a lack of information regarding the head activity used by people following stroke during dynamic, functional tasks. In order to address this gap in knowledge, a standardised test procedure, giving all subjects the same opportunity to move, was required. The first phase in the development of the HAT required its components to be identified, as well as the position of the subject and the tasks to be undertaken. As this work was exploratory, it is envisaged that the tasks will continue to be developed and refined, as the tool undergoes further validation.

2.3.1.a. Assessment position

In deciding the position of the subject, several factors were considered. In this early stage of tool development a single assessment position was thought to be appropriate, allowing between-task comparisons of head activity, as the base of support of the subject remains unchanged. As abnormalities of head activity are likely to be at their most severe in the early stages of recovery, the proposed position had to be appropriate for the assessment of patients with acute stroke. In the very acute stages following stroke, most patients are able to sit independently, but are frequently unable to transfer, stand, or walk, without assistance (Smith and Baer, 1999). Sitting is therefore frequently the position of choice used by therapists in the assessment and treatment of patients in the early stages of rehabilitation (Bobath, 1981). Having decided on the assessment position of sitting as the most appropriate for assessment of abnormalities of head activity in the very acute stages following stroke, the issue still remained as to whether supported or unsupported sitting would be the most suitable. Both positions have advantages. Unsupported sitting allows freedom of movement of the head and trunk, which is necessary if head activity relative to that of the trunk is to be assessed. It also negates the impact of any support on posture, which would be difficult to standardise whether provided by the chair, or by physical assistance. However, supported sitting would allow the head activity of patients without independent sitting balance to be rated, and it is also arguably the most common position used by patients during the day, with very little time spent in unsupported sitting in the acute recovery period following stroke. It was agreed, through group discussion, that the advantages attributed to unsupported sitting outweighed those of supported sitting. For this reason unsupported sitting was the chosen assessment position. It is acknowledged, however, that sitting is only one of several positions that could have been chosen.

2.3.1.b. Assessment Tasks

The next components of the assessment tool to be identified were the tasks during which assessment of head activity was to be made. A series of five short, simple tasks was developed comprising upright sitting, visual search, communication, eating, and reaching. Each task is either a simple everyday functional task, or represents a part of a functional task (visual search and reaching tasks). While the tasks themselves may not be completely new, having been developed from those identified in the literature, their combined use reflects a new step in the assessment of head activity following stroke, and provides a means of capturing the different roles of head activity.

The tasks chosen reflect everyday activities frequently undertaken by patients on a stroke unit (De Weerdt et al., 2000). De Weerdt and colleagues observed how stroke patients spent their daytime on two intensive rehabilitation units. The authors found that after therapy, the activities undertaken by the patients for the greatest amount of time were sitting, eating, and talking. Visual search and reaching were not specifically referred to in the study. The tasks chosen also reflect the activities frequently undertaken by patients during therapy in the acute phase of recovery following stroke. In the following section the development of each task is discussed in turn.

2.3.1.b.i Upright sitting

The first assessment task identified was an upright sitting task, capturing the role the head plays in postural control, and in the achievement and maintenance of an upright position. Subjects sit on a height adjustable plinth with knees at 90° flexion and feet flat on the floor, and standardised instructions are given. It is evident both from the literature and clinical experience that differing definitions of sitting balance, and different commands used in its assessment, are currently used for patients following acute stroke. Using sitting as a position within which to assess the quality of trunk posture in patients following acute stroke has been attempted previously (Carr and Shepherd, 1985;Collin and Wade, 1990; Taylor et al., 1994; Carr et al., 1990; Verheyden et al., 2004). However, only the study by Carr et al. (1999) rates the quality of head position. All these studies are discussed in more detail in Section 1.3.1.

2.3.1.b.ii Visual search

The second task identified was a visual search task, capturing the role the head plays in sensory interaction with the environment. Subjects search for a series of lights situated on a track around them, and count how many are on. The test is repeated 6 times, as repeated searching to both sides could potentially provide insight into any change in the search strategy used by subjects during the test. No single assessment or treatment method identified in the literature met the task criteria, and the visual search task was designed by incorporating elements from two of the identified measurement techniques.

To ensure that the task met the criteria set for the HAT it was essential that the visual search task allowed freedom of movement of the head on the trunk, did not require other motor responses to locate targets such as pointing, and did not require complex cognitive skills required for naming objects. Only two methods found in the literature allowed freedom of head and trunk movement (the modified Behavioural Inattention Test (Stone et al.,1992), and part of the Motor Assessment Scale (Carr et al., 1985)). The visual search task developed was based on the modified Behavioural Inattention Test (BIT) (Stone et al.,1992). The modified BIT requires subjects to look in both directions around a room to locate, by pointing, specifically placed objects. However, in the visual search task developed for the HAT the requirement for patients to point to the objects was omitted avoiding the need for a second motor response, and for recognising named objects. In the relevant tool item of the Motor Assessment Scale (Carr et al., 1985), seated subjects are required to turn and look behind without the use of upper limb support. Although the item met the task criteria, subjects are only required to look one way allowing differences in the subjects' ability (depending on the direction of the movement) to be missed. In addition, there is no measure or definition of how far round the subject must look to successfully "look behind".

The remaining method identified in the literature used a fixed head or trunk during the assessment of visual search. De Seze et al. (2001) looked at scanning and trunk rotation, using the Bon Saint Come device, as an intervention aimed at the treatment for unilateral neglect. The device consists of thoraco-lumbar vest with a vertical bar attached, which projects horizontally just above the patient's head and ends with a pointer 1.5m in front of the patient. The patient must make axial rotation of the trunk to displace the pointer laterally and explore the spatial field to locate a series of targets. Although the head is not fixed, the Bon Saint Come device requires trunk rotation to move the pointer to the target. Head movement without trunk rotation would not result in the pointer locating the target. It could be argued that the device could promote greater trunk rotation, and a more 'fixed' head and trunk movement than would naturally be required to visually locate the target. For this reason the use of the trunk to control target location was not used in the development of this visual search task. However, the equipment set-up used with the Bon Saint Come device contributed to the development of the visual search task.

<u>2.3.1.b.iii Communication</u>

The third task identified was the communication task, again capturing the role the head plays in sensory interaction with the environment, and any asymmetry in head activity that may be demonstrated. The subject of holidays was chosen for discussion, as it is one of a number of very normal topics that people following stroke wish to talk about (Ellis-Hill, 1999). Consideration was given to the emotive nature of the chosen topic, and although all topics could produce an emotional response, some, for example discussing family or home, were felt to be potentially overwhelming and inappropriate for the assessment of head activity in a research study. A mixture of open and closed questions was used to allow flexibility in the conversation, enabling the interviewer to open up or draw the dialogue to a close as required. The position of the interviewer, sitting at 45° to the subject on either side, was not found in the literature, but was used in an attempt to measure any differences in head activity used with respect to the position of the interviewer. The use of head movement in conversation has been researched to a very limited extent in people following stroke, with a greater emphasis on the use of upper limb gestures as a form of non-verbal communication (Blonder et al., 1994). Little comparison to the literature can therefore be made. From clinical experience it has been observed that attempts are frequently made to advise staff and visitors as to where to position themselves in relation to the patient when interacting with them. To date there is no evidence to support such advice in the promotion of recovery following stroke.

2.3.1.b.iv Eating

The fourth task identified was the eating task, capturing the role of the head in a coordinated movement with the trunk and upper limb. Any task requiring eating will exclude patients with dysphagia who are unable to swallow safely. Yoghurt was the chosen food as its consistency enables those on a soft or pureed diet to carry out the tasks, and because it can be eaten using a simple one-handed feeding action. The effects of various head and neck positions on swallowing have been shown in healthy adults and those with dysphagia by video fluoroscopy (Logemann et al., 1994, Castell et al., 1993), and by electrophysiological methods (Ertekin et al., 2001). Little is known, however, about the contribution head activity makes to the coordinated movements used during self-feeding in patients following stroke.

2.3.1.b.v Reaching

The final task to be identified was the reaching task, capturing the role the head plays in balance control. Reaching in sitting is frequently used as a balance retraining technique by physiotherapists in the rehabilitation of patients with acute stroke (Dean and Shepherd, 1997). More recently, reaching in sitting has been used as the task during which assessment of upper limb and trunk movement strategies have been investigated (Roby-Brami et al., 1997; Cristea and Levin, 2000; Michaelsen et al., 2001; Thielman et al., 2004). None of these studies, however, investigated head movement strategies. A reaching task in sitting is dynamically challenging, requiring subjects to move their centre of mass within their base of support. However, the support offered by sitting allows those with more severe balance impairment to attempt the task. In the reaching task subjects are requested to reach as far to the side or in front as possible whilst looking at a visual target located at eye level in front. Initially it was envisaged that a more functional reaching task would be used. A functional task, however, would require the use of vision to locate the target to be reached, and would consequently influence head activity. It was hoped that the use of a visual fixation would allow head movement associated with the reaching task to be described in terms of a balance response alone. Two directions of reach were chosen, reflecting those described in the literature, as each reach is likely to be accompanied by a different head activity. The Motor Assessment Scale uses both reaches as part of the assessment of balanced sitting (Carr et al., 1985). Campbell et al. (2001) investigated head and trunk movements in people following acute stroke during a dynamic lateral reach in sitting with a visual target directly in front of the subject. The lateral reaching task in sitting described by Campbell et al. (2001) has been replicated to form the lateral reaching task in the tool under development, and adapted for the forward reach.

2.3.1.c. Limitations of the assessment tool components

The standardised assessment tasks provide a means of assessing the different roles of head activity, and give each subject the same opportunity to demonstrate a given head activity. Limitations, however, arise due to the standardised test procedure, which by its very nature tests whether the subject demonstrates a head activity on that occasion, rather than consistently throughout the day.

Using the test only in sitting has limitations. In sitting the relatively low challenge placed on the postural control mechanisms (large and static base of support) could create a ceiling effect. Efforts have been made to prevent a ceiling effect by making some of the tasks dynamically challenging, increasing the demands on postural control. Evidence from clinical experience indicates that abnormalities of head activity following stroke will be seen in the sitting position in the very acute recovery phase. However, it remains feasible that subjects could demonstrate "normal" head activity in sitting, but with the greater challenge presented by standing, abnormalities may be evident. The single test position used in the development of the test prevents comparisons of head activity used during the same task carried out in different positions. For example, it will not be possible to compare the head activity used during reaching in sitting to that used during reaching in standing. This is acknowledged as a further limitation. Despite these limitations, it is hoped that information about head activity used in sitting will provide a good starting point for further work on the assessment of head activity during tasks in more dynamically challenging positions, for example where the base of support changes, in sit to stand, in standing, or during walking.

2.3.2 Phase 2: Identification of descriptors of head activity

Two hundred and sixty-three descriptors of head activity were identified from the five sources. For this study, descriptors of head activity were defined as *'terminology used to describe the clinically important aspects of head position or movement used by people in sitting'*. As head activity during dynamic functional activities cannot be assessed in isolation from the trunk, not least because head movement takes place at the cervical spine, descriptors of head activity in relation to the trunk, and combined head and trunk activity, were included within this definition. Wide boundaries of inclusion of descriptors were chosen in an attempt to include as many relevant descriptors as possible in a topic area where research to date is sparse.

Descriptors were identified from the five sources in an attempt to generate a variety of descriptors from differing perspectives; this was seen as strength of the tool development process. Potential research subjects (in this study patients with acute stroke) were recognised as an important source of descriptors, but they are frequently overlooked in tool development, resulting in tools that may not reflect the more subjective elements of the trait under investigation (Streiner and Norman, 2000). It was thought that by using both clinicians (coming from a patient assessment and treatment bias), and researchers (being more measurement orientated), different aspects of head activity would be identified.

Descriptors of head activity from published outcome measures, experimental papers, and those reported subjectively, were all included from the literature. Subjective reporting and theories of head activity were included as this represents a significant proportion of the literature on head activity following stroke. It was felt to be particularly important to include descriptors from the physiotherapy pioneers (Bobath, 1990; Carr et al., 1987; Brunnstrom, 1970; Knott and Voss, 1968), whose work traditionally underpins the therapeutic approach to the treatment of patients with stroke. Unfortunately, these treatment approaches currently rely on untested theory and anecdotal evidence to support their use, which in part reflects the paucity of research on the recovery of head activity following stroke.

Identifying descriptors from clinical practice (video recordings of patients during therapy sessions), allowed the identification of head activity used during a variety of activities and provided a more general picture of head activity than that seen during the specific assessment tasks. It was expected that large numbers of diverse descriptors would be identified from the recordings of therapy sessions. Interestingly and in contrast to what was expected, fewer descriptors were identified from the clinical practice source than either the researcher or clinician sources. One possible reason for this was that only patient therapy sessions were recorded and analysed with no contribution from healthy adults. It is not known what proportion of descriptors identified by clinicians or researchers related to the head activity of the healthy adults. Identifying descriptors from clinical practice enabled cross checking against descriptors identified from the tasks, providing evidence of content validity. The assessment tasks were frequently used as methods of treatment in the therapy sessions, and head activities identified during treatment sessions were similar to those identified during the assessment tasks.

The responses to interview questions regarding patients' difficulty moving their heads, difficulty seeing things around them, and any episodes of dizziness or feeling unbalanced were used as the patients' source of descriptors of head activity. Interestingly none of the seventeen patients interviewed reported any difficulty moving his or her head. Consideration of the responses about visual search, and feelings of dizziness and imbalance meant that indirectly reported difficulty with head movement was included from the patient's perspective. Patients identified only seven descriptors. This relatively small number was expected, as the scope for identification was only three interview questions, and from the researcher's clinical experience, few patients are known to perceive any problems relating to head activity, especially in the acute stages following stroke. Despite the low numbers, it is seen as a methodological strength to include the patient perspective.

A variety of descriptors were identified for each task. Some descriptors were very specific, referring to specific directions of movement or positions, for example "Head rotation with contra-lateral tilt", while others were more general, describing movement strategies or aspects of quality of movement, for example, "Increased hand to mouth activity to compensate for reduced head movement" and "Head fixed to trunk". Again the broad definition of descriptors of head activity and the different sources of descriptors helped provide this wealth of data. The number of descriptors identified for the tasks varied according to the source. Descriptors were well distributed between the tasks to which they relate with the most identified for reaching (eighty), and the least for eating (thirty-four). The number identified for reaching is likely to reflect both the relative wealth of literature on head activity as a balance response, and the number of therapists participating in the tool development process (both clinical and research), for whom reaching is an activity more frequently analysed.

The high number of descriptors of head activity (two hundred and sixty-three), identified from all five sources, is reflective of the wide boundaries of inclusion from the sources and the relatively loose definition of head activity used. However, such a broad search with very few constraints imposed was likely not only to identify as many relevant descriptors as possible, but also to produce a large overlap in descriptors from each source. Overlaps (where descriptors are similar but not exact duplicates), were evident from the lists compiled from the individual sources, making it apparent that a method of grouping the descriptors was required as the first stage in the short-listing process, if short-listing was to be meaningful. A decision was taken in this phase of the tool development to remove any measurement value pertaining to an individual descriptor. This was particularly relevant to descriptors identified from the literature. It is the researcher's experience that important descriptors risk being discounted in the short-listing stage if contaminated by measurement values thought to be inappropriate.

2.3.3 Phase 3: Short-listing the descriptors to form tool items

A two-stage approach was used in the short-listing of the 263 descriptors into a manageable number of measurable descriptors. In stage one, the descriptors of head activity were grouped according to themes. In stage two, measurable descriptors were identified, and defined to form tool items.

The first stage, grouping the descriptors into themes of head activity, attempted to address the large amount of overlap within the descriptors generated from each source. It was hoped that by grouping the descriptors a structure would be provided making any overlap and similarities explicit, without losing descriptors or terminology. Two researchers independently grouped the descriptors, and despite the terms used to describe the groups differing between the researchers, the contents of the groups were very similar for the upright sitting and eating tasks, and identical for the visual search, communication and reaching tasks. The apparent ease in grouping the descriptors suggests that each group described distinct features of head activity. The structuring of the 263 descriptors into just 20 groups provided a means of using the wealth of descriptor data in the second short-listing stage.

The group of researchers used in the second stage were experts in movement analysis. In exploratory work like this, the most appropriate method of identifying the measurable descriptors from the groups was deemed to be by group consensus. A measurable descriptor could only be identified from ten of the 20 groups. Many descriptors were deemed not to be measurable by video analysis, for example the whole group of descriptors of 'swallowing position' was eliminated, as it was felt impossible to identify when swallowing occurred. The loss of descriptors of 'quality of movement' was a recurrent theme running through the short-listing process. It is well known that aspects of quality of movement are often difficult to measure, and physiotherapists frequently cite the lack of measurement of quality of movement as a negative feature of the outcome measures they use. In the development of a clinical tool to assess sitting balance after stroke Nieuwboer et al. (1995) describe the difficulties they had assessing quality, with only one of the six tool items describing quality of movement in sitting being rated reliably. Two descriptors of quality of movement were identified as measurable in this tool, and each forms a sub-item; in sitting the quality of the correcting movement is rated, and in the visual search task the quality of head and trunk movement is described. However, with all the tool items rating the movement strategy used during a task, rather than a measure of ability to accomplish the task, the whole tool itself could be argued to assess quality of movement.

Descriptors that did not directly refer to head activity but were associated features, such as distance reached and speed of reach, were eliminated from the short-list. These descriptors were identified as impacting on the head activity used during reaching, but were not felt appropriate for inclusion on the head activity assessment tool. Both distance reached and the time taken to reach the maximum distance could, in the future, be used in conjunction with the analysis of head activity. In this way any association between head activity and the distance reached and the speed of movement could be described.

One possible weakness of the short-listing stage of the tool development process is the use of researchers already used in the tool development process; however, their expertise cannot be overlooked. One of the researchers grouping the descriptors had not previously been involved in the tool development process, which went some way to address this weakness, but it was not feasible to recruit a new team of experts for the second short-listing stage.

Throughout the tool development process consideration was given as to whether to keep the descriptors generated for individual tasks separate, or combine them into a single long list. Maintaining the separate lists meant that the key measurable descriptors for each task could be identified, i.e. assessment of head activity was task specific. Combining the lists would have meant that the descriptors identified described head activity more globally. It was felt that at this time the task-specific approach was more suitable. In the future development of the tool, it may prove to be more appropriate to adopt a less rigid approach.

2.3.4 Phase 4: Designing the assessment tool

In the fourth phase of the tool development process the ten measurable descriptors of head activity were converted into unambiguously worded, clearly defined, scored tool items. Any relevant measurement values removed in phase 2 of the development process formed the starting point in the group discussion to identify the measurement method for each tool item.

A maximum of four items are rated per task. The rating of any more items for a single position or task runs the risk of making the tool too complex, this is arguably one of the limitations of the tool reported by Carr et al. (1999). The authors describe a tool developed to rate postural observations of patients following stroke in sitting, supine, and side lying. Nineteen aspects of posture are rated for a single position. If the tool developed in this study has the potential for future development into a live rated clinical tool, the minimum possible number of items to be observed per task, (whilst maintaining the validity of the tool), is likely to be most effective. The method of scoring was also kept simple, with a majority of the tool items being scored on a dichotomous scale. However, an increasing number of categories does not necessarily reduce the reliability of the tool item (Streiner and Norman, 1996) and the tool includes items rated using three, four, and, for the rating of head position, six categories. Although arithmetically simple, the system used to score the HAT has a subtle form of weighting. With each task having a different number of scored tool items, the tasks do not contribute equally to the total HAT score. It can be argued, however, that this weighting is appropriate as the number of scored tool items relates back to the number of descriptors and themes identified for each task.

The final stage of phase four was the design of a user-friendly format for the Head Activity Test (HAT).

To date it is not possible to say which components of the HAT have influence on its total score. With more data, a multiple regression analysis could be run to see which items and weighting could improve the predictive ability of the HAT. Simplification in rating the HAT would be apposite before the tool could be advocated for routine clinical use. With its further use with larger numbers of patients with stroke it may be appropriate to reduce the number of tasks and/or the number of items rated per task.

2.4 Conclusion

A video-rated observational tool to assess the head activity used by people following acute stroke, 'The HAT', has been designed. In the following chapter the processes undertaken so far to establish the validity and reliability of the new tool are described.

Chapter 3

Criterion establishment of the HAT

Section 3A

External criterion validity of the HAT

3A.1 Introduction

In this chapter the first steps in establishing the external criterion validity of the new tool are described. This investigation is a crucial step in the early development of the tool, but, as with every measurement tool, estimates of its validity (and reliability) should be constantly refined with use.

3A.2 Background

In the process of developing a new assessment tool it is essential to determine if the scale is measuring the purpose for which it was designed, or in other words, that the scale is valid, and that valid conclusions can be drawn from its results. There are several types of validity that contribute to the confidence that can be placed in the inferences drawn from the scale's score (Streiner and Norman 1995). Whether an assessment tool has enough items, and adequately covers the domain under investigation is referred to as ***content validity***. The content validity of the HAT was discussed in Chapter 2. ***Criterion validity*** (sometimes referred to as ***concurrent validity***), refers to 'the correlation of the scale with some other measure of the trait or disorder for which it was developed, ideally a gold standard, which has been used and accepted in the field' (Streiner and Norman 1995). ***Construct validity*** refers to the accuracy of the inferences that can be derived from measuring the 'construct' for which the tool was developed. Although methodologically different from content and criterion validity, as Guion (1977) stressed, 'all validity is at its base some form of construct validity...it is the basic meaning of validity'. Establishing construct validity is an ongoing process and is discussed in more detail in Section 6.4.6.

3A.2.1 Aim of the study

To establish the external criterion validity of the newly developed, video-rated, HAT.

3A.3 Methods

3A.3.1 Study design

This correlation study was conducted to establish whether or not results obtained from the video-rated HAT were comparable with results obtained using a 'gold standard' motion analysis system (Polaris). Polaris, a three-dimensional motion tracking system, was chosen as the external criterion measure. Both measures were used simultaneously to record the movements of participants as they carried out the tasks that form the HAT. The results obtained from rating the HAT from the video recordings were then compared with the results obtained by Polaris in a two-stage process.

3A.3.2 Participants

The two-stage validation of the HAT required the use of two participant samples. In stage one, the boundaries for the Polaris data were identified and defined to allow the continuous angular data to be converted into categorical data for comparison with the HAT. A convenience sub-sample of between five and ten healthy adult subjects from the study reported in Section 4A, was identified to participate in the first stage of this study.

In stage two of the validation study, the HAT results were compared with the results obtained from Polaris. A convenience sub-sample of between five and ten patients from the study reported in Section 4B was identified. Data were collected at the patient's second assessment (three weeks post stroke).

3A.3.3 Equipment

3A.3.3.a Video-recorder

A Sony digital camcorder DCR-PC1E was situated on a tripod 1.5m in front of the seated participant with the lens set to approximately eye level. For the eating and lateral reach tasks the camera position was moved to the side of the subject, contra-lateral to the arm with which the subject reached in line with the HAT protocol (see Appendix I).

3A.3.3.b Polaris

Polaris is a portable three-dimensional motion tracking system made by Northern Digital Inc. (NDI). The Polaris system is opto-electric and tracks markers in real time. The system identifies an arrangement of markers that are labelled as a 'tool'. However, to ease differentiation between the HAT and Polaris, the Polaris tools will be referred to as marker configurations. The Polaris system comprises a position sensor, which has two cameras mounted in a single unit with fixed positions relative to each other (see figure 3A.1). Surrounding each camera is a ring of infrared emitters that illuminate the retro-reflective passive markers. The marker reflections are recorded by the cameras and tracked via a personal computer. The recording volume is pyramidal, extending to a maximum of approximately 1.2m by 1.2m at a distance of 2.4m from the position sensor. A diagrammatic representation of the recording volume is presented in figure 3A.2.

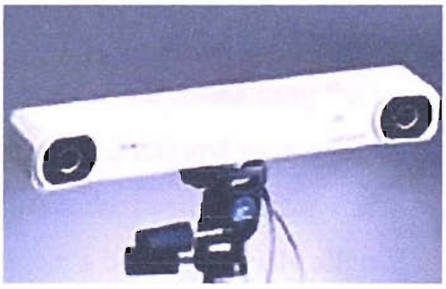

Figure 3A.1 Polaris position sensor

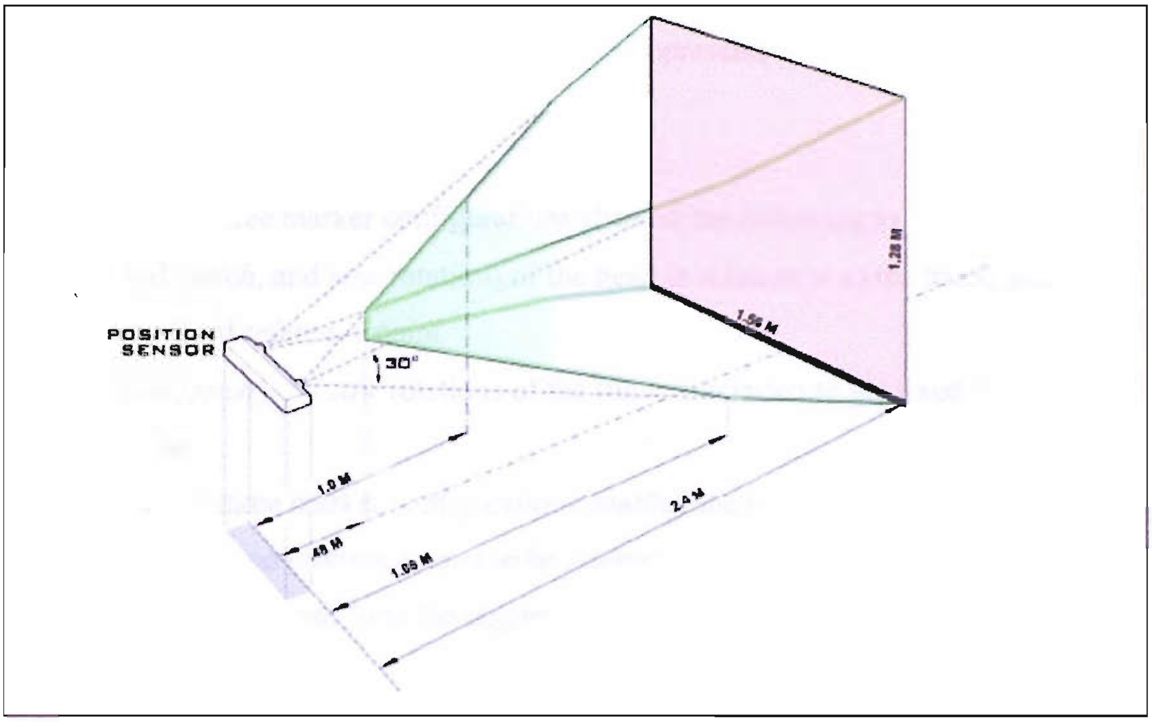

Figure 3A.2 Polaris recording volume

<u>3A.3.3.b.i Polaris marker configurations</u>

In this study Polaris was used with three marker configurations, each comprising three markers lying in a single plane. The centre of one of the three markers was defined as the origin of the marker configuration's local coordinate system. Marker configuration one (measuring the position of the head) was attached to a CROM (see Section 4A.2.3.c.i) and worn on the subject's head. Marker configuration two, (measuring the position of the trunk), was attached with a chest strap and worn on the subject's back, vertically aligned with the spinal processes of the thoracic spine, with the top of the tool aligned with T5. The third marker configuration (the "fixed" room reference) was placed on a stool next to the plinth on which the subject sat. All marker configurations are illustrated in figure 3A.3.

The data that are returned by Polaris are the three-dimensional co-ordinates of the origin of the marker configuration's local coordinate system. Results are reported as *Roll*, *Pitch*, and *Yaw* rotations of each of the marker configurations. *Roll* refers to rotation in the frontal plane, which represents the movements clinically referred to as left or right side (or lateral) flexion. *Pitch* refers to rotation in the sagittal plane, which represents the movements clinically known as flexion and extension. *Yaw* refers to rotation in the transverse plane, which represents the movement clinically referred to as left or right rotation.

The use of the three marker configurations allowed the following to be reported:

- *Roll*, *pitch*, and *yaw* rotations of the head in relation to a) the trunk, and b) the fixed reference point.
- *Roll*, *pitch*, and *yaw* rotations of the trunk in relation to the fixed reference point.

The use of the three marker configurations enabled the position of the head in relation to the fixed reference point to be interpreted with respect to both the degree of head movement alone, *and* the degree of head movement as a result of trunk movement.

Figure 3A.3 Polaris marker configurations

3A.3.4 Procedure

The Polaris unit was situated behind and slightly above the participant. The exact positioning of Polaris varied between subjects and was defined as the position that gave the optimal view of all three marker configurations during the pre-test check procedure.

The Polaris and video equipment were set up prior to the participant entering the room. Participants were familiarised with the equipment, and fitted with head and trunk marker configurations. The fixed room reference marker configuration was positioned. Participants then completed the HAT following the protocol as outlined in Appendix I. Performances were simultaneously recorded on video and Polaris.

3A.4 Results

3A.4.1 Stage one – Defining Polaris data boundaries for categorisation

3A.4.1.a Sample

A sample of six healthy adults was recruited. The sample consisted of 2 men and 4 women, with a median age of 56 (range 49-66).

3A.4.1.b Polaris data boundaries

To enable comparison between the HAT and the three-dimensional motion data, the angular data from Polaris were converted into categorical data using boundaries identified from the healthy adult sample. Firstly, the guidelines and definition of terms (see Appendix II) for rating the HAT were used to identify the appropriate set or sets of Polaris data from which the boundaries were set. For example, if the HAT rating involved an estimation of head rotation in relation to the environment (e.g. the tool item 'search strategy' for the visual search task), then the Polaris data selected would include the *yaw* data for head relative to the fixed reference. Having identified the data set(s), and rotation(s) from which to compare the HAT and Polaris data, it was then necessary to define the boundaries for the Polaris data, enabling it to be categorised. The boundaries were set using the upper and lower limits of the data observed in the healthy adult sample. The boundaries for each category were quantified using the mean, plus or minus two standard deviations of the mean, from the relevant healthy adult results. Two standard deviations were used so that 95% of the healthy adult data relevant to the category would be included, but any outlying results would be outside the defined boundaries.

For the HAT items rated dichotomously (the majority of tool items), the boundaries were set for the category that was predominantly demonstrated by the healthy adult sample. For the remaining categories the criteria were defined simply as not meeting the criteria set for the rival category. For example, for the tool item 'head upright' for the upright sitting task the rating categories are "YES" and "NO". In the healthy adult sample the "YES" category was predominantly demonstrated. The boundaries were therefore set for the "YES" category (using the method detailed in Appendix V), and the "NO" category was simply defined as not achieving the criteria for "YES".

The method of setting the rating boundaries for the four tool items rated using more than two categories are outlined below:

- For the tool item 'head position' of the upright sitting task, the rating boundaries for each category were set as the largest amplitude of head rotation.
- For the tool item 'search strategy' of the visual search task, the boundaries of the "both ways" category were defined using the mean and two standard deviations of the healthy adult results. None of the healthy adults demonstrated either of the remaining two categories. The definitions of the categories "one way" and "incomplete search" were based on a combination of the definitions and guidelines for rating the HAT (see Appendix II), and not meeting the "both ways" criteria (see table 3A.2).
- For the tool item 'orientation of the head' of the communication task, boundaries for both the "towards" and "towards and away" categories were defined using the mean and two standard deviations of the healthy adult results, as both categories were demonstrated by the healthy adult sample.

The boundaries for the remaining category "away" were defined as not meeting either of the other two category criteria (see table 3A.3).

- For the tool item 'feeding action' of the eating task, boundaries for the "meet in the middle" category were defined using the mean and two standard deviations of the healthy adult data (all healthy adults demonstrated this strategy). The boundaries for the "arm only" category were defined as not meeting the "meet in the middle" criterion in relation to the trunk relative fixed reference data set, and for the "head to pot" category as not meeting the "meet in the middle" criterion in relation to the head relative trunk data set (see table 4.4).

Polaris data was not categorised for the following three HAT tool items:

Use of selective movement	- Upright Sitting Task
Use of head for gestures	- Communication Task
Size of gestures	- Communication Task

For these tool items the quality of movement is rated, or the movements used are rapid and of relatively small amplitude, making them unsuitable for analysis with Polaris data.

A detailed example of how the Polaris data boundaries were set for the tool item rating categories is presented in Appendix V. The Polaris boundary definitions relating to all categories used to rate the HAT are presented in the following five tables: table 3A.1 Upright sitting task, table 3A.2 Visual search task, table 3A.3 Communication task, table 3A.4 Eating task, and table 3A.5 Reaching task.

HAT Tool Item	HAT category	Definition of Polaris score boundary
Upright sitting		
Attempt to correct	Yes	Trunk relative fixed: There is ≥ 7° pitch preceding the "upright sitting position"
	No	Trunk relative fixed: There is < 7° pitch preceding the "upright sitting position"
Selective movement		**Not rated with Polaris**
Trunk upright	Yes	Trunk relative fixed: At a single time point a position is achieved of ≤ 23° pitch from neutral, ≤ 6° roll from neutral, and ≤ 5° yaw from neutral
	No	Trunk relative fixed: Failure to meet all three "YES" category boundary criteria
Head upright	Yes	Head relative fixed: At a single time point a position is achieved of ≤ 10° pitch from neutral, ≤6° roll from neutral, and ≤ 5° yaw from neutral
	No	Head relative fixed: Failure to meet all three "YES" category boundary criteria
Position	Flexion	Head relative fixed: The largest amplitude of rotation is +ve pitch
	Extension	Head relative fixed: The largest amplitude of rotation is -ve pitch
	Side-flexion	Head relative fixed: The largest amplitude of rotation is direction specified roll
	Rotation	Head relative fixed: The largest amplitude of rotation is direction specified yaw
Maintained	Yes	Head relative fixed: The upright head position "YES" is maintained for 200 Polaris samples Trunk relative fixed: The upright trunk position "YES" is maintained for 200 Polaris samples
	No	Head relative fixed: Failure to meet *and* maintain all three "YES" category boundary criteria for head upright Trunk relative fixed: Failure to meet *and* maintain all three "YES" category boundary criteria for trunk upright

Table 3A.1 Definitions of Polaris boundaries for rating the sitting task

HAT Tool Item	HAT category	Definition of Polaris score boundary
Visual search		
Search strategy	Both ways	Head relative fixed: There is ≥ 45° yaw in both directions from the starting position
	One way	Head relative fixed: There is ≥ 45° yaw in one direction only from the starting position
	Incomplete search	Head relative fixed: There is < 45° yaw from the starting position in both directions
Trunk movement	Yes	Trunk relative fixed: There is ≥ 13° yaw in either direction from the starting position
	No	Trunk relative fixed: There is < 13° yaw in both directions from the starting position
Quality of trunk movement	Rigid	Head relative trunk: There is < 25° yaw in both directions from the starting point
	Free	Head relative trunk: There is ≥ 25 ° yaw in either direction from the starting position

Table 3A.2 Definitions of Polaris boundaries for rating the visual search task

HAT Tool Item	HAT category	Definition of Polaris score boundary
Communication		
Head orientation	Away	Head relative fixed: No yaw rotation ≥18° from neutral towards the researcher occurs throughout the episode of communication
	Towards	Head relative fixed: ≥18° yaw from neutral towards the researcher is maintained throughout the episode of communication
	Towards and away	Head relative fixed: Variable positions used including ≥18° yaw towards the researcher *and* yaw rotation in the opposite direction to at least neutral.
Use of head for gesture		**Not rated with Polaris**
Gesture size		**Not rated with Polaris**

Table 3A.3 Definitions of Polaris boundaries for rating the communication task

HAT Tool Item	HAT category	Definition of Polaris score boundary
Eating		
Feeding action	Meet in the middle	Head relative trunk: ≥ 10° -ve pitch from the starting position Trunk relative fixed: ≥10° +ve pitch from the starting position
	Arm only	Trunk relative fixed: <10° +ve pitch from the starting position
	Head to pot	Head relative trunk: <10° -ve pitch from the starting position Trunk relative fixed: ≥10° +ve pitch from the starting position

Table 3A.4 Definitions of Polaris boundaries for rating the eating task

HAT Tool Item	HAT category	Definition of Polaris score boundary
Forward Reach		
Counterbalances with head	YES	Head relative trunk: ≥ 30°-ve pitch from the starting position Head relative fixed: At peak of reach (maximum trunk pitch) head pitch is ≤ +/- 7° from neutral
	NO	Failure to meet both "YES" category boundary criteria
Lateral Reach		
Counterbalances with head	YES	Head relative trunk: ≥ 8° roll from the starting position in the opposite direction to trunk roll. Head relative fixed: At the peak of the reach (maximum trunk roll) head roll is ≤ +/-10° from neutral.
	NO	Failure to meet both "YES" category boundary criteria

Table 3A.5 Definitions of Polaris boundaries for rating the reaching task

3A.4.1.c Summary of stage 1 – Defining Polaris data boundaries for categorisation

Boundaries identified from the healthy adult sample were used to convert the continuous angular data from Polaris into categorical data. Polaris data boundaries were defined for 12 out of the 15 HAT tool items. Having defined the Polaris data boundaries, the next step in establishing the external criterion validity of the HAT was to compare the results from the video-rated HAT with the Polaris ratings.

3A.4.2 Stage 2 – Comparing the HAT with Polaris

The categorical rating results from the HAT and Polaris were compared using two methods: the kappa measure of agreement, as described by Altman (1991), and percentage agreement. This two-fold approach, recommended by Brennan and Hays (1992), addresses the weaknesses that could have resulted if either test had been used in isolation.

To calculate the kappa values, the ratings given by the HAT and Polaris were cross-tabulated and the number of exact agreements observed. A percentage of exact agreement was calculated by dividing this number by the total number of paired ratings. Agreements by chance were then calculated by summing the expected frequencies of the cells in the cross-tabulation. The agreement between methods was then expressed as a proportion of 'the scope for doing better than chance'. The kappa value lies between zero and one, between agreement that is no better than chance, and perfect agreement.

Landis and Koch (1971) suggested guidelines for interpreting *k* values:

***k* value**	**Agreement**
<0.20	Poor
0.21-0.40	Fair
0.41-0.60	Moderate
0.61- 0.80	Good
0.81-1.0	Very good

Table 3A.6 Interpreting Kappa values

The video rating of the HAT for each patient was compared with the Polaris rating, on data recorded simultaneously. The HAT ratings were compared with the ratings from Polaris for 12 out of the 15 HAT tool items, as described previously.

3A.4.2.a Sample

The patients recruited to the validation study were a sub-sample of convenience from the sample of patients recruited to the study of head activity following stroke (presented in Section 4B). Seven patients were recruited from the thirteen patients assessed at week three following stroke (assessment 2). Figure 3A.4 outlines the recruitment of the patient sample to stage two of the validation study.

The sample consisted of five men and two women, with a median age of 77 (range 64 to 84). Three patients had lacunar infarcts, two had partial anterior infarcts, and two had a primary intra-cerebral haemorrhage. The median number of days since stroke was 24 (range 19-25).

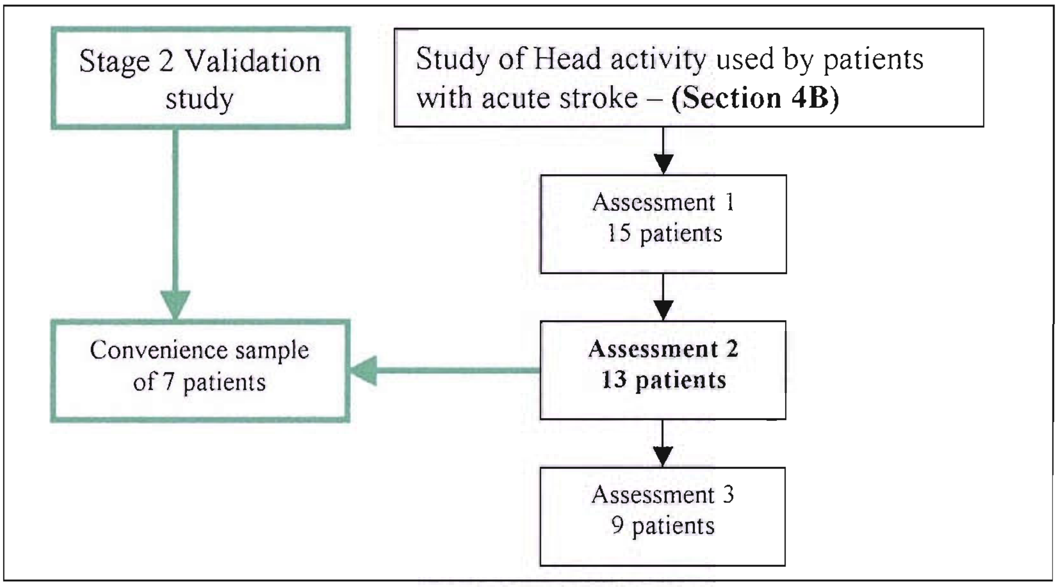

Figure 3A.4 Patient sample – stage two of the validation study

3A.4.2.b Agreement between video-rated HAT and Polaris ratings

<u>3A.4.2.b.i Agreement on Upright Sitting</u>

The percentage agreement and kappa value of agreement for the comparison of the HAT results with the Polaris data for all but one tool item (use of selective movement) used to rate the upright sitting task are presented in table 3A.7.

Tool Item	n	% Agreement	Kappa value
Attempt to correct	6	100	1
Trunk upright	7	100	1
Head upright	7	86	.696
Position	3	100	1
Maintained	4	100	1

Table 3A.7 Agreement between HAT and Polaris for the Upright sitting task

Agreement between Polaris and the HAT was reached for all patient ratings on 'attempt to correct' (k=1); incomplete Polaris data prevented one comparison. However, all patients were rated in the same category (YES). Agreement on 'trunk upright' was achieved for all patients (k=1), and both categories were used. For 'head upright', agreement was reached for six out of the seven ratings (*k*=.696). One patient being rated as having an upright head by the HAT, but not by Polaris, accounted for the disagreement. Agreement was reached on 'head position' for the ratings of the three patients not achieving an upright head. Agreement was achieved between Polaris and video that the position was maintained for the four patients rated as achieving upright head and trunk positions using video (*k*=1).

3A.4.2.b.ii Agreement on Visual Search

The percentage agreement and kappa value of agreement for the comparison of the HAT results with the Polaris data for all tool items used to rate the visual search task are presented in table 3A.8.

Tool item	n	% Agreement	Kappa value
Search strategy	7	100	1
Trunk movement	7	100	1
Quality of trunk movement	7	100	1

Table 3A.8 Agreement between HAT and Polaris for the Visual search task

One hundred percent agreement was achieved for all items rated for the visual search task (*k*=1). Only the 'head moves both ways' category was used for rating the search strategy. Both categories were used for rating trunk movement, but only the 'freely' category was used to rate quality of trunk movement.

3A.4.2.b.iii Agreement on Communication

The percentage agreement and kappa value of agreement for the comparison of the HAT results with the Polaris data for the tool item 'head orientation' for the communication task are presented in table 3A.9. The results for 'orientation of the head' to the left and right have been summed. Missing Polaris data prevented the comparison to one side for one patient.

Tool item	n	% Agreement	Kappa value
Head orientation	13	77	.552

Table 3A.9 Agreement between HAT and Polaris for the Communication task

Agreement was achieved for 10 out of the 13 ratings for head orientation (*k*=*.552*). All three disagreements were accounted for by patients being rated as using 'towards and away' by video, but 'towards' by Polaris.

3A.4.2.b.iv Agreement on Eating

The percentage agreement and kappa value of agreement for the comparison of the HAT results with the Polaris data for the tool items used to rate the eating task are presented in table 3A.10.

Tool item	n	% Agreement	Kappa value
Feeding action	7	100	1

Table 3A.10 Agreement between HAT and Polaris for the Eating task

One hundred percent agreement was achieved when comparing the ratings for the feeding action (*k*=1). The 'meet in the middle' and the 'arm only' strategies were rated.

3A.4.2.b.v Agreement on Reaching

The percentage agreement and kappa value of agreement for the comparison of the HAT results with the Polaris data for the tool item used to rate each reach are presented in table 3A.11. Technical difficulties meant that one patient's Polaris data was of too poor a quality to analyse.

Tool item	n	% Agreement	Kappa value
Forward Reach			
Counterbalances with head	6	100	1
Lateral Reach			
Counterbalances with head	6	100	1

Table 3A.11 Agreement between HAT and Polaris for the Reaching task

Agreement was reached between Polaris and video for all six ratings of counterbalancing with head on both forward and lateral reach (*k*=1). Both categories were rated for both reaches.

An Example of the comparisons made between the Polaris data and the video-rated HAT for the lateral reach are shown in figures 3A.5–3A.10. In figure 3A.5 a still from the video recording of a subject ***demonstrating*** a head counterbalancing reaction is presented. In figures 3A.6 and 3A.7 the graphical representation of the Polaris results for the head relative to the trunk, and the head relative to the fixed room reference, recorded at the same time, are presented. The category boundaries are shown in pink on the Polaris graphs. In figure 3A.8 a still from the video recording of a subject ***failing to demonstrate*** a head counterbalancing reaction is presented. In figures 3A.9 and 3A.10 the graphical representation of the Polaris results recorded at the same time are presented.

Figure 3A.5 Video still: Counterbalances with head – YES

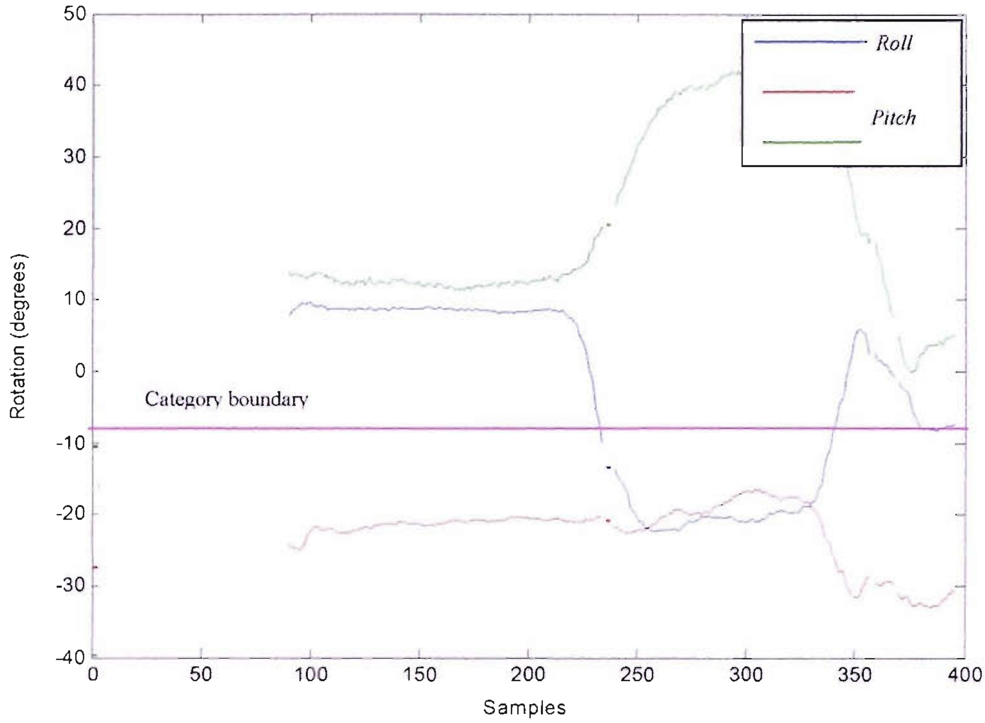

Figure 3A.6 Polaris data for head relative to trunk: Counterbalances with head – YES

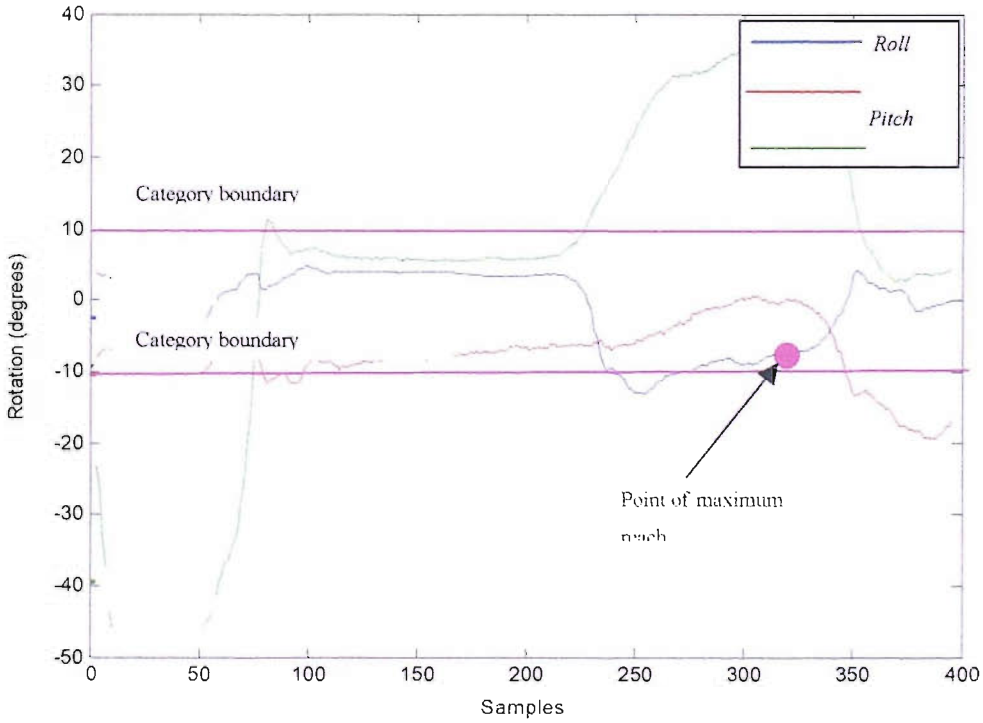

Figure 3A.7 Polaris data for head relative to fixed reference: Counterbalances with head – YES

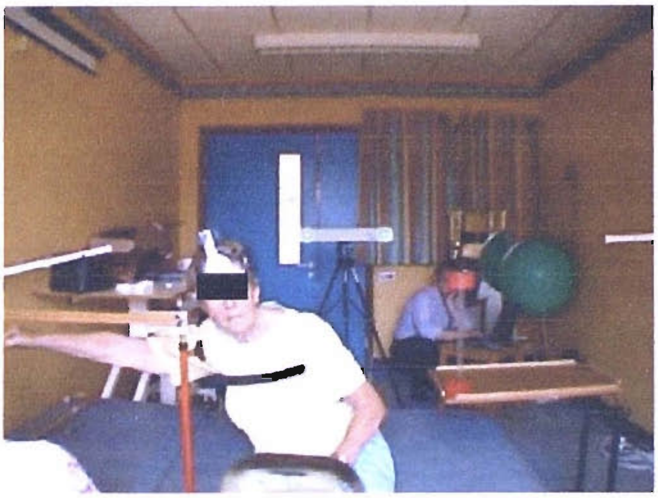

Figure 3A.8 Video still: Counterbalances with head – No

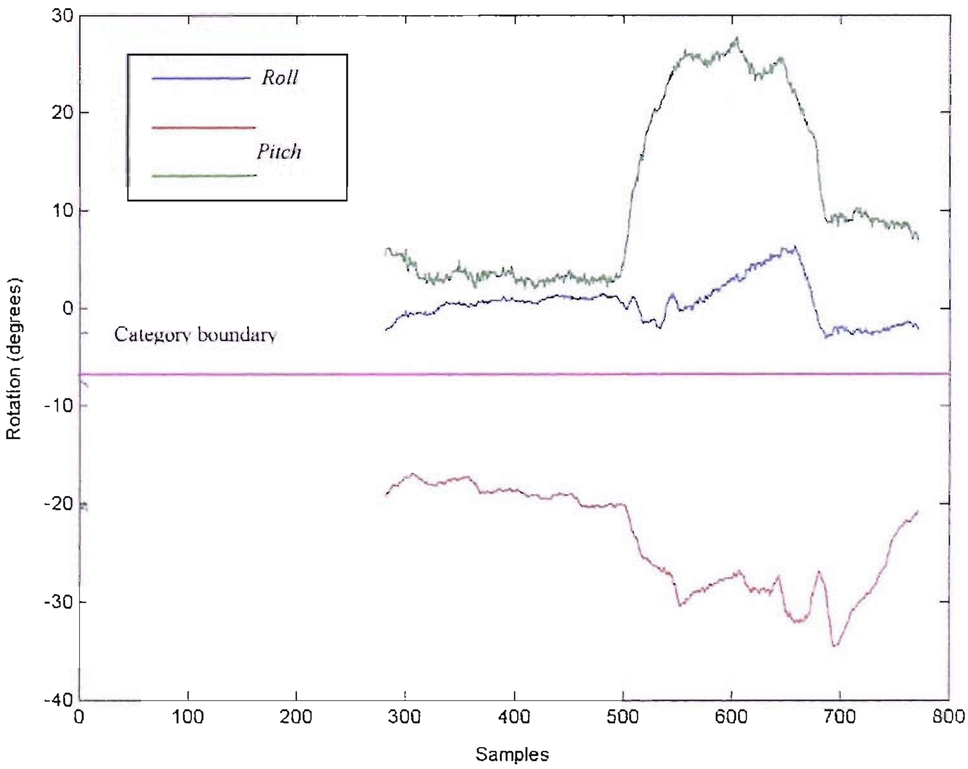

Figure 3A.9 Polaris data for head relative to trunk: Counterbalances with head – NO

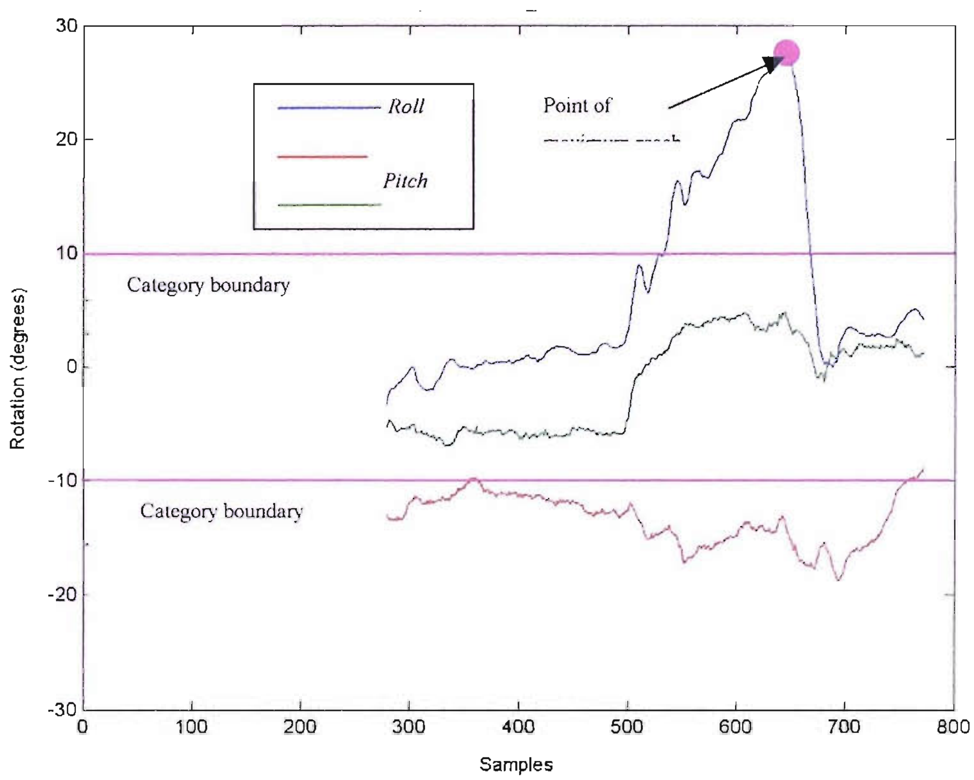

Figure 3A.10 Polaris data for head relative to fixed reference: Counterbalances with head – NO

3A.4.2.c Summary of stage 2 results – Comparison of HAT and Polaris results

The ratings from the HAT and the Polaris data for 12 out of the 15 HAT tool items were compared. Video-rating the HAT produced results comparable with Polaris for all but one of the tool items compared, when tested on a small sample of patients with acute stroke, the population for which the HAT was developed. The tool item failing to reach an acceptable level of agreement was "orientation of the head" for the communication task. The results are summarised for each task.

Upright sitting

- Agreement rating all tool items from video and Polaris was good to very good (*k*=.667-1).

Visual search

- Agreement rating 'search strategy', 'trunk movement' and 'quality of trunk movement' was very good (*k* = 1).

Communication

- Agreement rating 'head orientation' was only moderate (*k* = .552).

Eating

- Agreement rating 'feeding action' was very good (k=1).

Reaching

- Agreement rating 'counterbalancing with head' on the forward reach was very good (k=1).
- Agreement rating 'counterbalancing with head' on the lateral reach was very good (k=1).

Section 3B

Reliability of the HAT

3B.1 Introduction

The reliability of a measurement tool reflects the amount of error, systematic and random, inherent within the tool (Dijkers et al.,2002). Inter-rater reliability reflects the level of agreement between different observers evaluating the same event at the same point in time. Intra-rater reliability reflects the level of agreement between repeated ratings of the same event by an individual observer. This two-phase study was designed to test the reliability with which the researcher rated the HAT. All tool items were suitable for estimation of inter-rater and intra-rater reliability.

3B.1.2 Aim of the study

To establish the inter-rater and intra-rater reliability of each of the tool items.

3B.2 Phase 1

3B.2.1 Methods

Attempts were made to limit the impact of the 'halo effect' (Thorndike, 1920) on the reliability of rating the tool items. Thorndike described the 'halo effect' as the rating of items based on a global impression of the subject, rather than the individual aspect of the subject's performance of interest, resulting in biases in responding. In the development of the HAT, several methods were undertaken to minimise the 'halo effect'. Firstly, by using very different tasks to assess head activity, the potential for the rating of one task influencing the rating of another is arguably less than if the tasks were very similar. In addition, the tight definitions of the rating categories, and editing the video recordings, showing the raters only the relevant timeframes of each task to be rated, should also have contributed to minimising the 'halo effect'.

3B.2.1.a Sample

The patients recruited to the reliability study were the same sample of 20 patients recruited to the observational study of head activity under taken in phase 2 of the tool development process for the identification of descriptors (see Section 2.2.2.). Figure 3B.1 outlines the recruitment of the patient sample to the reliability study. Two experienced physiotherapists (raters 2 and 3) and the researcher (rater 1) were recruited as observers. Raters 2 and 3 had not seen or used the tool before. All observers had at least six years experience in the treatment of patients with acute stroke.

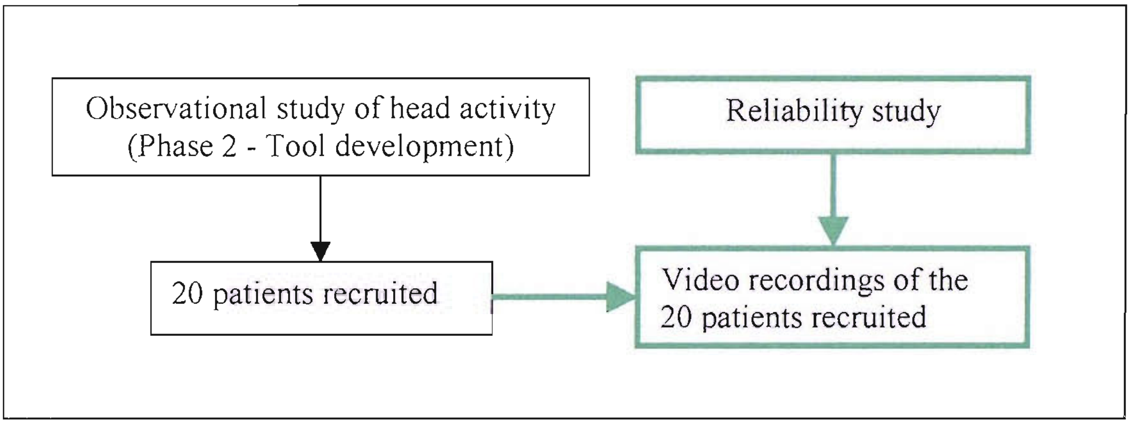

Figure 3B.1 Patient sample – the reliability study

3B.2.1.b Procedure

The patients completed the HAT following the protocol (see Appendix I), and their performance was recorded on video. The video recordings were edited so that all subjects demonstrated each task in turn. All other material was removed from the recordings. The observers independently rated each patient demonstrating all five tasks.

3B.2.1.b.i Inter-rater reliability

All three observers were used to test the inter-rater reliability of the tool items. All raters had copies of the definitions and guidelines for use of the HAT (see Appendix II). Rater 1 instructed raters 2 and 3 in the use of the HAT. Training comprised a group session during which the head activity of four patients randomly selected from the 20 recruited to the study were rated. Comparisons of observers' ratings were made after each subject, the results discussed, and any issues arising clarified. Training took approximately 45 minutes. The three observers then used the HAT to independently rate head activity from the remaining 16 video-recordings of subjects carrying out the assessment tasks. The observers watched the recordings at normal speed, with repeated viewing and slow play as required.

3B.2.1.b.ii Intra-rater reliability

Rater 1 (the researcher) re-rated the sixteen video recordings of subjects carrying out the assessment tasks, two weeks later.

3B.2.1.c Analysis

The inter-rater reliability of the individual tool items was established by testing the levels of agreement between the three raters, and between each pair of raters. The intra-rater reliability of each tool item was established by testing the level of agreement between the ratings of rater one made on two separate occasions. The level of agreement for both inter- and intra-rater reliability was calculated using percentage agreement and the kappa coefficient (Cohen, 1960). Acceptable levels of agreement were set at greater than or equal to 70% agreement (Brennan and Hays, 1992), and a kappa coefficient of greater than or equal to 0.6 (Landis and Koch, 1977); see Section 3A.4.2 for more details. The kappa coefficient tests the level of agreement taking into account the proportion of agreement expected by chance. Percentage agreement was used in conjunction with the kappa coefficient in an attempt to address the anomalies that can arise from using the kappa coefficient for unbalanced and/or asymmetrically distributed ratings (Feinstein and Cicchetti, 1990).

3B.2.2 Results

3B.2.2.a Inter-rater reliability

3B.2.2.a.i Agreement between all three raters

Nine out of the ten tool items reached acceptable levels of agreement (percentage agreement > 70 *and* $k > 0.6$). Tool item 9, rating the counterbalancing of the head on the forward reach as "yes" or "no", failed to reach acceptable levels of agreement for both percentage agreement and the kappa coefficient. The results of the levels of agreement between all three raters are presented in table 3B.1; results that failed to reach acceptable levels are shown in red.

Assessment Task	Item no.	Tool Item	Percentage Agreement	Combined Kappa Statistic
Upright sitting	1	Attempt to correct	100	1
	1.i	Selective movement	90	0.84
	2	Trunk upright	100	1
	3	Head Upright	83	0.73
	3.i	Head position	78	0.77
	4	Maintained	100	1
Visual search	5	Search strategy	100	1
	5.i	Trunk movement	86	0.70
	5.ii	Head and trunk	100	1
Communication	6	Head orientation	84	0.91
	7	Gesture use	100	1
	7.i	Gesture grade	91	0.79
Eating	8	Feeding action	93	0.71
Reaching	9	Counterbalances with head on Forward reach	69	0.57
	10	Counterbalances with head on Lateral reach	88	0.81

Table 3B.1 Agreement between all three raters

3B.2.2.a.ii Agreement between pairs of raters

Eight out of the ten tool items reached acceptable levels of agreement, between all pairs of raters. The results of the agreement between pairs of raters are presented in table 3B.2; results that failed to reach acceptable levels are shown in red. Tool item 3 (including 3.i), rating head upright as "yes" or "no" and the position of the head (if not upright) on a six-point scale, reached acceptable levels for percentage agreement but just failed to reach acceptable levels of agreement for the kappa coefficient. For item 3, the failure to reach an acceptable level of agreement occurred between raters 1 and 3. In this case, a disproportionately low kappa coefficient compared to percentage agreement is evident. Tool item 9, rating the counterbalancing of the head on forward reaching, again as "yes" or "no", failed to reach acceptable levels of agreement for both percentage agreement and the kappa coefficient for the pairs of raters 1'v'3 and 2'v'3. For all tool item ratings, disagreements were spread throughout the subjects with a maximum of three disagreements occurring for any single subject.

Assessment task	Item no.	Tool item	Rater 1 'v' Rater 2		Rater 1 'v' Rater 3		Rater 2 'v' Rater 3	
			Percentage agreement (%)	Kappa coefficient	Percentage agreement (%)	Kappa coefficient	Percentage agreement (%)	Kappa coefficient
Upright sitting	1	Attempt to correct	100	1	100	1	100	1
	1.i	Selective movement	90	0.78	90	0.78	90	0.78
	2	Trunk upright	100	1	100	1	100	1
	3	Head Upright	92	81	83	0.54	92	0.81
	3.i	Head position	71	0.57	71	0.57	100	1
	4	Maintained	100	1	100	1	100	1
Visual search	5	Search strategy	100	1	100	1	100	1
	5.i	Trunk movement	87	0.60	87	0.66	87	0.61
	5.ii	Head and trunk	100	1	100	1	100	1
Communi-cation	6	Head orientation	88	0.74	91	0.80	97	0.93
	7	Gesture use	100	1	100	1	100	1
	7.i	Gesture grade	94	0.86	94	0.86	94	0.86
Eating	8	Feeding action	93	0.88	93	88	100	1
Reaching	9	Counterbalances with head on forward reach	94	0.88	75	0.50	69	0.42
	10	Counterbalances with head on lateral reach	88	0.66	88	0.66	94	0.88

Table 3B.2 Agreement between pairs of raters

Further analysis of the results for tool item 9, 'Counterbalances with head', for the forward reaching task revealed that disagreements occurred in the same direction, and that data was unevenly distributed between the categories. Table 3B.3 shows the raw data in a 2 by 2 table, for the agreement between raters 2 and 3. The table illustrates the disagreements occurring in one direction, with rater 2 rating no, and rater three yes, for all disagreements (as shown in red).

	Rater 2			
Rater 3	Counterbalances with head	Yes	No	
	Yes	7	5	12
	No	0	4	4
		7	9	16

Table 3B.3 Raw data counterbalances with head

3B.2.2.b Intra-rater reliability

All tool items reached acceptable levels of agreement for intra-rater reliability. Levels of agreement were consistently higher than levels for inter-rater agreement. Only seven disagreements occurred in total, and a maximum of two disagreements occurred for any single tool item. The rating disagreements were evenly distributed throughout the subjects, with no subject having more than one disagreement. The results of the intra-rater agreement are presented in table 3B.4.

Assessment task	Item no.	Tool item	Percentage agreement (%)	Kappa coefficient
Upright sitting	1	Attempt to correct	100	1
	1.i	Selective movement	100	1
	2	Trunk upright	92	0.83
	3	Head Upright	100	1
	3.i	Head position	92	0.85
	4	Maintained	Not tested	Not tested
Visual search	5	Search strategy	100	1
	5.i	Trunk movement	100	1
	5.ii	Head and trunk	100	1
Communication	6	Head orientation	100	1
	7	Gesture use	100	1
	7.i	Gesture grade	94	0.86
Eating	8	Feeding action	100	1
Reaching	9	Counterbalances with head on forward reach	88	0.75
	10	Counterbalances with head on lateral reach	94	0.85

Table 3B.4 Intra-rater agreement

3B.2.2.c Summary of results – Phase one

- Nine out of the ten tool items reached acceptable levels of inter-rater agreement between all three raters.
    - Tool item 9 did not reach acceptable levels of reliability.
- Eight out of the ten tool items reached acceptable levels of inter-rater agreement between all three pairs of raters.
    - Tool items 3 and 9 did not reach acceptable levels of reliability.
    - Failure of tool item 9 to reach acceptable levels of agreement was consistent for both percentage agreement and the kappa coefficient.
    - Failure of tool item 3 to reach acceptable levels of agreement was for two out of the three pairs of raters, and for the kappa coefficient only.

3B.3 Phase 2

Further analysis of the raw data and feedback from the raters provided information as to possible causes of the unacceptable levels of agreement for tool items 3 and 9. For tool item 9, amendments were made to the HAT protocol and rating guidelines. In its revised form, the forward reach was filmed from the side (non-affected / non-dominant) of the subject (as opposed to from in front). This modification was made to improve the view of head pitch relative to the trunk. The boundary definitions of the rating categories were tightened. For tool item 3, the likely explanation for the lower than expected kappa coefficients was the unbalanced distribution of the raw data and the consequent kappa anomaly (Feinstein and Cicchetti, 1990). The acceptable levels of percentage agreement support this thinking. For this reason tool item 3 remained unchanged and reliability was not further tested.

3B.3.1 Methods

In phase 2 of establishing the reliability of the HAT the reliability of tool item 9 'counter balancing with the head' on the Forward reach was re-tested using the modified version.

3B.3.1.a Sample

The sample comprised ten patients randomly selected from the patients recruited to the study presented in Section 4B (Head activity used by patients in the first six weeks following acute stroke). Raters 1 and 3 from phase one of the reliability study (Section 3B.2.1.a) were recruited as observers.

3B.3.1.b Procedure

The patients completed tool item 9 of the HAT following the amended protocol and their performance was recorded on video. The observers independently rated each patient demonstrating the forward reach using the new category boundary definitions. The observers watched the recordings at normal speed with repeat viewing and slow play as required.

3B.3.1.c Analysis

The level of agreement between the two raters was calculated using both percentage agreement and the Kappa coefficient (Cohen 1960).

3B.3.2 Results

Agreement between the raters was reached for all ten ratings of counterbalancing with the head on the forward reach (100% agreement, k=1).

3B.3.2.a Summary of results – Phase two

The modified version of tool item 9 'counterbalancing with the head on the forward reach' reached acceptable levels of agreement (100% agreement, k=1).

Section 3C
Discussion of the criterion establishment of the HAT

3C.1 Discussion of the criterion establishment of the HAT

In Sections 3A and 3B, the external criterion validity and the reliability of the HAT were described. In the following sections, the results from these two studies are discussed, the study limitations highlighted, and the early development of the HAT is summarised.

3C.1.1 Establishing the external criterion validity of the HAT

As discussed previously, there are no available data with which to compare the results of this study. The published observational assessments of sitting balance or sitting position, which do include items relating to head and trunk position (Taylor, 1994; Nieuwboer, 1995; Carr et al., 1999; Verheyden, 2004), have not been tested against an external criterion.

3C.1.1.a Sample

Estimates of validity depend on the nature of the sample and the circumstances of the assessment. 'Every time a scale is used with a different group of people it is necessary to re-establish its properties' (Streiner and Norman 1995). The data set used in this study was small and of limited variability. The patient sample was from the second assessment, and, despite being only three weeks following stroke, when variability in physical ability was expected to be relatively high, some of the rating categories remained unused. The second assessment was felt to be the earliest assessment appropriate for patients to undergo the lengthier procedure necessitated by using Polaris. However, the HAT results from patients assessed one week following stroke (presented in Section 4B), suggest that a more acute sample would have necessitated the use of an increased number of rating categories. Further criterion validation of the HAT with larger, and more varied (including more acute) samples, would advance the understanding of its validity.

3C.1.1.b Equipment

Polaris was chosen as the external criterion measure primarily for its portability, enabling its use in the acute clinical setting. One disadvantage of using Polaris was its small recording volume. Despite careful positioning of the Position Sensor Unit to achieve maximum data recording, occasionally some data, particularly at the end of range, were missing. Missing end-of-range data was known to be a potential study weakness at the outset, but was considered out-weighed by the advantages of using three-dimensional motion analysis in the acute clinical setting for externally validating the HAT. Additionally, it was not thought that end-of-range measurement would impact on the primary use of Polaris as the external criterion measure. In these circumstances it was predicted that the boundaries would most likely be set as 'greater than' or 'less than' a value rather than defining maximum or minimum values. Passive markers were used with the Polaris system (as opposed to active markers), as the use of passive markers avoids the need for cables that run between the tool (attached to the subject) and the tool interface unit. A further manufacturer-reported advantage of passive tools is that the number of tools used does not affect the sample rate.

3C.1.1.c Defining the boundaries

The 'true' values of the individual tool items are not known; only video and Polaris ratings were known. In order to compare the ratings from each system the Polaris data had to be categorised, necessitating the defining of each category's boundary in terms of the Polaris output; the degree of rotation in each of the three planes. The objective assessment of head activity is a relatively new concept and the terms used in the HAT, for example "counter-balancing with the head", have not previously been defined in terms of degrees of rotation. This is in contrast, for example, to the agreed objective definition that exists defining a step. The boundaries set for each tool item to categorise the Polaris data were based upon the HAT definitions and guidelines for use (see Appendix II), and the results from the healthy adult sample. The method of using the mean and two standard deviations of the relevant healthy adult data to set the category boundaries meant that each rating category was defined by the healthy adult data, with the exclusion of any extreme results. The results of the Polaris data boundary setting were largely as expected. The healthy adult Polaris data were very consistent for each HAT tool item category. This was not surprising when the consistency of the healthy adult HAT results, presented in Section 4A, is considered. There were no extreme Polaris results for the small sample of healthy adults used in this study. There was, however, one unexpected result from the Polaris boundary definitions; the degree of *pitch* included within the definition of 'trunk upright', for the upright sitting task, was larger than expected. This meant that subjects with up to 23° of trunk flexion or extension would be rated (using the HAT) as sitting with an upright trunk. In contrast to the amplitude of *pitch*, the degree of *roll* and *yaw* allowed are much smaller, 6° and 5° respectively. The larger than expected boundary for trunk pitch for the tool item 'upright trunk' illustrates the complex relationship between clinical judgement and meaning, and accurate objective measurement. For example a position rated as upright by observation from video is not necessarily equal to the true objectively defined upright. The extent of the Polaris boundaries set in this work reflects the acknowledged limited accuracy of visual estimation from video recordings.

Boundaries were not set for the tool items 'use of selective movement' in the upright sitting task, or 'use of the head for gestures' and 'gesture size' in the communication task. As a result, comparisons were not undertaken between the ratings by video and Polaris for these tool items. The 'use of selective movement', a concept of quality of movement felt to be important by physiotherapists, could not be defined in terms of Polaris output (degrees of rotation). One appropriate criterion measure would be the consensus opinion of an expert panel. At this early point in the development of the HAT, it having been used only by the researcher, an expert panel was not available. For the tool items 'use of the head for gestures' and 'gesture size' it was felt that the movements were too rapid and small to accurately set boundaries for at this stage in the tool development process, especially with consideration given to the limitations of the Polaris data. The external criterion validity of all three tool items needs to be addressed with use of the HAT in further studies.

3C.1.1.d Agreement between ratings

With the data including a preponderance of one value over others for some of the tool items, agreement by chance alone would be high, resulting in an elevated estimate of percentage agreement. For this reason the kappa statistic was also presented. However, again due to the uneven spread of the raw data between categories, and the small sample size, consideration was given to the kappa paradoxes produced in such circumstances (Feinstein and Cicchetti, 1990). In the calculation of the kappa value, the assumption is made that the expected values for agreement depend on the marginal totals. An example of the kappa paradox can be seen when comparing the percentage agreement for 'orientation of the head' of the communication task (77%) with the kappa value (*k*=.552). The lower than expected kappa value is accounted for by the asymmetrical imbalance of the marginal totals caused by the predominance of rating "towards" over "towards and away". This illustrates the requirement for caution when interpreting both percentage agreement and the kappa statistic into clinical meaning.

An acceptable level of agreement was achieved for all but one of the twelve HAT tool items rated, using the two methods of measurement. This relatively high degree of agreement is not surprising when the gross and simple measurement method used by the video-rated HAT is considered. Correspondingly gross and simple boundary definitions were set for categorising the Polaris data. This meant that within each rating category the data fits the guidelines and definitions for the video-rated HAT (see Appendix II), and the boundaries set for Polaris (see Section 3A.4.1.b), but variability can also exist.

3C.1.2 Establishing the reliability of the HAT

Both percentage agreement and the kappa statistic were used for the analysis of the data to establish the reliability of the tool items. This two-fold approach, recommended by Brennan and Hays (1992), addresses the weaknesses that would have resulted if either test had been used in isolation. As the group of subjects being rated were patients in the first six weeks following stroke, there was a possibility of a preponderance of one value over others for some tool items, making agreement by chance alone, potentially high. Such preponderance results in an elevated estimate of percentage agreement, necessitating the use of the kappa statistic along side. However, again due to the predicted uneven spread of the raw data between categories, and the small sample size, consideration was given to the kappa paradoxes produced in such circumstances (Feinstein and Cicchetti, 1990).

Initially, in establishing the inter-rater agreement, the level of agreement between all three raters was calculated. Calculation of the combined agreement between all raters has the potential to mask problems between pairs of raters and may result in an inflated estimate of the reliability of the tool items. Agreement between pairs of raters was therefore calculated. It was only on closer analysis of the raw data from the levels of agreement between pairs of raters that information as to the rater specific frequency and direction of disagreements were obtained. Where distribution of the raw data is not even between categories, Brennan and Silman (1992) suggest that more emphasis should be placed on the raw data. Analysis of the raw data was essential in unmasking the possible causes of the disagreements (a crucial step at this early stage of the tool development process) and contributed to the attempts to increase the reliability of the tool.

For tool item 3, 'upright head', agreement between raters 1 and 3 failed to reach an acceptable level. In this case, a disproportionately low kappa coefficient compared to percentage agreement is evident. Further analysis of the raw data revealed an uneven *spread* of data between categories. With 83% agreement between raters 1 and 3, and both other pairs of raters having acceptable levels of agreement, it seems likely that the low kappa is an example of the kappa paradox (Feinstein and Cicchetti, 1990). For this reason no changes to the tool item were made. For item 3.i, 'head position', the relatively low number of subjects (eight) rated in this sub-category, and the six categories used to rate head position explains, at least in part, the low kappa coefficient. Again, no changes to the tool item were felt to be necessary at this stage in the tool development process.

Using the initial protocol for the HAT, all raters remarked that the position of the camera in front of the patient made rating counterbalancing of the head more difficult for the forward reach than the lateral reach, i.e. rating head *pitch* relative to the trunk in the sagittal plane was more difficult than rating head *yaw* in the frontal plane when the recordings were taken from directly in front of the patient. In light of this, the definition of counterbalancing of the head for the forward reach was tightened, and the recording procedure changed so that the forward reach was recorded from the affected side (non-dominant side in controls), enabling improved observation of head pitch relative to the trunk. Retesting the reliability of rating tool item 9, using the modified version of the HAT and a different sample of patients, produced 100% agreement between two raters. Both raters reported increased ease in viewing head pitch relative to the trunk with filming from the side. In light of this finding, it is the modified version of the HAT that is used in the subsequent studies.

Not surprisingly, levels of intra-rater agreement, testing the agreement of a single rater (the tool developer) over time, were greater than inter-rater agreement. Looking in more detail at the intra-rater agreement data, a maximum of one disagreement per subject was evident. The spread of disagreement among subjects is indicative of the absence of a subject type that is 'difficult' to rate. This was supported by the inter rater-reliability results, with a relatively even distribution of disagreements among individual subjects.

Despite attempts to reduce the impact of the 'Halo Effect', it remains possible that it was a source of the disagreements seen. This was perhaps true for the original version of tool item 9 rating 'counterbalancing of the head' on the forward reach. In this case, the aspect of the subject's performance being rated was difficult to observe. With a more global observation, based on the subjects' performance of other tasks, or more likely, other components of the reaching task such as hesitancy or speed, a bias in rater response could have occurred.

In the absence of measures of head activity reported in the literature, comparisons of the reliability of the HAT with other assessment tools are limited. However, some comparisons can be made with measures where head activity and/or trunk activity of patients with stroke are included as part of a broader assessment. One observational assessment tool that categorically rated head activity was identified (Carr et al., 1999). In addition, three studies (Verheyden et al., 2004; Nieuwboer et al., 1995; Taylor et al., 1994) using measures that rated trunk alignment in sitting were identified. Each study reported the reliability of the individual tool items, and in the following section these results are discussed in relation to the reliability of the HAT.

In a study to test the reliability of a tool under development to record the resting postures of patient with stroke, Carr et al. (1999) recorded the head position of patients in sitting as part of the posture rating. The rating of head position required the scoring of the degree of cervical lateral flexion on a six-point scale, the degree of cervical rotation on a six-point scale, and the degree of cervical flexion on a five-point scale. In addition, the degree of trunk lateral flexion and rotation were both recorded on four-point scales. The scales were presented pictorially. Pairs of observers made live ratings of patients' postures simultaneously. The reliability of three pairs of raters, each pair assessing between 10 and 35 patients, was reported. Reliability was calculated using percentage agreement. Only seven out of 15 (three sets of five pairs of ratings) (47%) of the observations of head and trunk positions reached an acceptable level of agreement (> 70%). Kappa coefficients were initially presented but the authors felt that the uneven distribution of ratings throughout the categories resulted in a kappa value that was difficult to interpret and analysis of the kappa coefficient was abandoned.

In the assessment tool reported by Carr et al. (1999), two likely reasons for the poor reliability results for the rating of head and trunk posture are the complexity and the live nature of the ratings required. Each position had a corresponding large number of categories and a large number of positions were rated simultaneously. In addition, the rating of head and trunk position was part of a broader rating of posture, including detailed rating of all four limb positions. Live rating meant that no record of the patient's posture was captured by video or photograph, preventing the testing of intra-rater reliability and limiting the further analysis of the inter-rater reliability problems encountered. Photography (video or still) enables revisiting of the ratings and discussion between observers, both of which can assist in identifying possible causes of poor reliability. A further limitation was the failure of the authors to undertake further analysis of the kappa coefficient, resulting in a lack of information as to the distribution of disagreements between both categories and raters. In contrast to the tool reported by Carr et al. (1999), three steps taken in the development of the HAT to maximise its reliability were the use of video recordings, the development of a simple rating scale, and the analysis of the raw data from the calculation of the kappa coefficients.

Nieuwboer et al. (1995) reported the development of an observational tool to measure sitting balance in people following stroke. The authors attempted to include a measure of posture quality as part of the assessment. A 12-item scale was developed, of which six items rate the quality of trunk alignment or movement in different sitting positions. The six items of quality rated were: symmetry of the trunk in sitting in both the frontal and sagittal planes, each rated on a 3-point scale; quality of lumbar flexion and extension in sitting, rated on a 2-point scale; symmetry of the trunk in cross-legged sitting in both the frontal and sagittal planes, rated on a 3-point scale; quality of trunk elongation when leaning on each elbow, rated on a 2-point scale; and quality of leaning forwards, again on a 2-point scale. The authors found reliability of $k<0.6$ for five of the six items rating quality. Only quality of leaning forwards, rated as symmetrical or not, reached acceptable levels of agreement $k=0.64$. The authors propose several possible reasons for the poor reliability of rating the remaining items. Firstly, there was considerable difference in the experience of the two raters, one senior and one junior therapist. The authors also suggest that a lack of clarity in the definitions of the categories could have contributed to the poor reliability. Finally they put forward the idea that quality of motor performance does not seem to lend itself to objective measurement. Again the assessment was not recorded on video, limiting further analysis of the disagreements.

Verheyden et al. (2004) describe the development of the Trunk Impairment Scale (TIS). The TIS is a categorically rated observational tool used to measure motor impairment of the trunk in sitting after stroke. The scale consists of 17 tool items each rated on a scale of between two and four points. Rating categories are gross, and clearly defined. Inter-rater reliability was reported as acceptable ($k>0.6$) for 15 out of the 17 tool items. The remaining two tool items had high percentage agreement (>88%), and the authors suggest that the uneven distribution of the data within the rating categories accounts for the relatively low kappa values rather than poor reliability. Unfortunately, no video recordings were taken so further exploration of the reliability results was not possible.

Taylor et al. (1994) undertook a study looking at the relationship between symmetry of trunk posture in sitting, motor function, and unilateral neglect. The symmetry of the trunk posture in acute stroke patients was rated live using live postural observation. Trunk symmetry was rated on a four-point assessment scale, rating the trunk as midline, leaning to the affected side, leaning to the unaffected side, or unable to sit. To test the inter- and intra-rater reliability of this assessment photographs were taken of eight patients instructed to sit upright. Six raters independently categorised the patients on two occasions one week apart. One hundred percent agreement for inter- and intra-rater reliability was reported. The authors suggest the high percentage agreement was attributable to the crude rating categories.

In light of the suggestions of Nieuwboer et al. (1995), and the poor reliability results of Carr et al. (1999), a simple categorical tool, with a limited number of categories and tight definitions, seems to be imperative in the observational rating of head and trunk activity. The reliability results from Taylor et al. (1994) and Verheyden et al. (2004) support this thinking. It is suggested that the favourable reliability results obtained for the HAT reflect the tool's limited number of grossly rated categories and the use of video recordings allowing repeated viewing of the head activity being rated.

3C.1.2 Study limitations

In the validation study the question, 'Do the methods agree well enough for one to replace the other?' (Altman, 1994) was asked, i.e. did the simple categorical rating of the HAT from video-recordings generate findings comparable with those produced by Polaris, the accepted external criterion measure? In the reliability study the question, 'How much error lies within the HAT?' was asked. In attempting to answer these questions the study limitations must be taken into account.

3C.1.2.a Sample

The major limitation of the studies was the small sample size and its limited variability. The small sample size affected the relative distribution of data within the categories, and meant that certain categories of head activity, potentially describing less frequently employed strategies, remained unused. This meant that in the validity and reliability studies, comparisons for rating some of the tool item categories were not possible. There exists the possibility, therefore, that the estimates of validity and reliability are biased. However, it was the 'extreme' categories that remained un-rated, and therefore not compared (for example the category "away" for the tool item 'orientation of the head' of the communication task). Although acknowledged as a limitation, it is arguably these extreme categories that are most likely to have the best agreement between the two methods of rating (Polaris and the HAT), and between raters. The use of the tool on a larger cohort of subjects in future studies will provide data for further validity and reliability testing, helping to address these limitations.

An additional limitation in the testing of the reliability of the HAT was the use of the same video recordings as drawn on for the identification of the assessment tasks. It could be argued that this may have produced more favourable reliability data due to the tool items having been developed, in part, from movement strategies demonstrated by this subject group.

3C.1.2.b Equipment

Using Polaris as the 'gold standard' introduced several limitations to the study. However, the fact that Polaris was a portable three-dimensional motion tracking system that could be used in the acute clinical setting weighed in its favour. No other measurement device that met these two criteria (deemed essential by the researcher), was available at the time and in the location of the study.

Firstly, the small recording volume resulted in some missing data despite efforts to the contrary. Another significant limitation of Polaris was the unreliability of its sampling rate. In discussion with the manufacturer (Northern Digital Inc.) it was confirmed that the sampling rate, when using passive markers, could be affected by the number of marker configurations used, and the communication speed to the host PC. In addition, questions were raised as to the effect on the sampling rate if one of the marker configurations went out of the recording volume. Fortunately, only one tool item ('maintained' for the upright sitting task) rates a time-dependent feature of head activity. When defining the Polaris boundaries for this tool item the measure of time was kept as the number of samples and not converted to seconds. A further limitation encountered in using Polaris was in the reporting of dual and triple axis rotations, i.e. combined movements. Polaris calculates angle change between marker configuration positions using a set order of rotations. These rotations are about the axis of the marker configuration, which changes throughout the movement process. Therefore, the rotations reported do not always correlate with rotations relative to a fixed room reference. The discrepancies reported to date have been in the order of approximately +/-5° (Burnett, 2002). In contrast to Polaris, judgements of head activity made from video-recordings, as used in rating the HAT, are made relative to a fixed room reference. For this reason disparities between the results from the video-rated HAT and the Polaris data were expected. However, because of the gross rating system used by the HAT, the possible variation of +/-5° in the Polaris results does not seem to have impacted on the comparison of the HAT and the categorised Polaris results. Extreme care would, however, be required if the Polaris results were to be interpreted in greater detail. Both the limitations of the sampling rate and the combined movement results are discussed further in Section 5.4.8.

An additional limitation of the Polaris data was the number of marker configurations used in the study. Although using the three marker configurations (head, trunk and fixed room reference) meant that head position and movement could be interpreted in relation to the contribution made by trunk movement, no information about other body parts was available. This is a limitation, particularly of the more dynamic tasks, e.g. visual search and reaching, where information regarding the position and movement at the pelvis and feet particularly, would have been of interest. In addition, no force measurements were made relating to the symmetry of weight bearing in sitting. When designing this study great consideration was given to the acute condition of the sample, the location of the data collection and the early exploratory nature of the work being undertaken. However, in future studies, data regarding the position and movement of the subject's pelvis and limbs and the forces generated during the tasks would be invaluable.

In planning this study, consideration was given to using alternative laboratory-based motion analysis systems. These had the advantages of smaller markers, larger recording volumes and greater accuracy. However, the overriding issue in choosing the 'gold standard' with which to compare the HAT ratings was that the HAT was developed for use with patients with acute stroke. The external criterion validity of the HAT therefore needed to be tested on a sample from the population for whom it was developed. For this reason Polaris was chosen over more widely used laboratory-based systems. For a discussion of the advantages some available laboratorybased systems have over Polaris, and their possible role in the further validation of the HAT, see Section 5.4.8.e.

3C.1.2.c Procedure

Another potential source of bias in the validation process was that the researcher rated both the video-recordings and the Polaris data. Attempts were made to reduce the bias; the two measurement methods were analysed separately, and at least six months apart. However, the potential for bias still exists and must be considered in interpreting the results. Finally, in any concurrent criterion validation process the results are dependent on the reliability of the criterion measure with which the new tool is correlated. The reliability of using Polaris to measure head movement has not been tested to date. Streiner and Norman (1995) suggest that the most realistic stance is that perfect reliability never really exists in either the new measurement tool, or the criterion measure with which it is compared.

In the reliability study, using rater 1 to train raters 2 and 3 can also be seen as a limitation. However, rater 1, having developed the tool, was the expert and the only person able to train other raters. It was also imperative that the reliability (both inter- and intra-rater) of rater 1 using the HAT was tested, as rater 1 would use the HAT in the studies looking at head activity in both healthy adults and patients with stroke (presented in Sections 4A and 4B respectively). Despite this limitation, a strength of the training process was the group training and discussion undertaken.

3C.2. Summary

The HAT produced results that were comparable with a gold standard motion analysis system for all but one of the HAT tool items tested. The tool item failing to reach an acceptable level of agreement was "orientation of the head" in the communication task. Disagreement between the HAT and Polaris was for the 'towards' and the 'towards and away' categories. As these categories are not distinguished when scoring the HAT, no change to the HAT was made at this point in the tool development process. Following modifications to the HAT all ten tool items reached acceptable levels of inter- and intra-rater reliability. It is expected that with the use of the HAT with increased numbers of subjects in the future, additional modifications will be made to further improve the tool's validity and reliability.

3C.3 Conclusion

The validation and reliability studies undertaken in the preliminary development of the HAT demonstrated that the HAT had the potential to be used in the investigations for which it had been designed. The first uses of the HAT to characterise the head activity used by a sample of healthy adults and a sample of patients with acute stroke are described in the following chapter (Sections 4A and 4B respectively). Refinement of the estimates of validity and reliability would be expected when the HAT is used in further studies, and when used by other researchers.

Chapter 4

Characteristics of the head activity used by older healthy adults and patients following acute stroke

Section 4A

Head activity used by older healthy adults during functional activities in sitting

4A.1 Introduction

The majority of research into head activity has focused on the responses of healthy adults to external perturbations (e.g. Buchanan and Horak, 2001; Allum et al., 1997), or that used during complex, demanding tasks in standing, (e.g. Pozzo et al., 1991). Little is known about head activity during simple, seated, functional tasks. The results from this study will provide a description of the "typical" patterns of head activity used by healthy older adults during seated functional tasks. This will provide the data for comparison with the head activity of patients with acute stroke, for whom the HAT was specifically designed.

4A.1.1 Aims of the study

i. To describe the head activity used by healthy adults during simple seated functional tasks.
ii. To describe changes in head activity over a four-week period.

4A.2. Methods

4A.2.1 Study design

This study was an observational investigation of a small sample of healthy older adults.

4A.2.2 Sample

A sample of convenience was recruited from the visitors and staff of Christchurch Hospital Stroke Unit, and the staff of Southampton University Rehabilitation Research Unit.

4A.2.2.b Inclusion criteria:

Participants were included in the study if they were:

- Over 40 years of age
- Able to give written informed consent

4A.2.2.b Exclusion criteria:

Participants were excluded if they had a history of:

- Neurological disorder, including stroke
- Vestibular dysfunction or other balance disorder
- Pre-existing visual impairment not corrected for by glasses
- Severe cervical spine dysfunction

4A.2.3 Procedure

4A.2.3.a Ethical approval

Permission to conduct the study was granted by the Local Research Ethics Committee and The Royal Bournemouth and Christchurch Hospitals NHS Trust Research and Development Committee (see Appendix VII c & d).

4A.2.3.b Recruitment

The study took place at Southampton General Hospital gait laboratory and the treatment room on the Stroke Rehabilitation Unit at Christchurch Hospital. Potential participants were approached in person by the researcher and invited to take part. Each subject was invited to participate on a single occasion, and if possible, on two further occasions.

4A.2.3.c Assessments

Participants were assessed on up to three occasions with two weeks between each assessment. Assessment timings approximated those used in the patient study (presented in Section 4B). Assessments took approximately 30 minutes and were carried out at a time convenient to the participant. Basic demographic data of the participant's age, gender, and hand dominance were recorded at the first assessment.

4A.2.3.c.i Measures

The following measures were included in the study and were undertaken at each assessment:

- Assessment of cervical spine range of movement
- Assessment of head activity using the HAT
- Seated forward and lateral reach distance (recorded in conjunction with the HAT)
- Head activity interview

*Measurement of cervical spine range of movement using the CROM**

Active Cervical spine range of movement was measured using the Cervical Range of Movement Device (the CROM*) following the manufacturer's protocol. The CROM consists of a clear plastic frame that is mounted over the subject's bridge of the nose and ears and secured at the back of the head with a strap (see figures 4A.1 and 4A.2). Range of movement is indicated by three dial angle meters attached to the frame and arranged orthogonally. Neck flexion and extension and side flexion movements are recorded by gravity inclinometers. Rotation is recorded by a compass goniometer and operated in conjunction with a shoulder-mounted magnetic yolk. The dial meters are each marked in 2° intervals. The maximum active range of movement in each of the three cardinal planes, sagittal (flexion/extension), frontal (side flexion), transverse (rotation) was recorded on a single occasion. Range of movement was measured in supported sitting, with the participant seated on a chair with a thoracic spine rest, but without arms. Participants were requested to move their heads as far as possible, in the specified direction, without moving their shoulders. Range of flexion and extension, and right and left side flexion were read (to the nearest degree), from the gravity inclinometers located on the side and front of the CROM respectively. Right and left rotation were read from the magnetic goniometer located on the top of the CROM. For calculation of active range of movement for each half-cycle (e.g. right and left rotation separately), starting position was taken as neutral. Active range of flexion, extension, side flexion, and rotation were classed as being within the "normal" range for this age group or not. The "normal" ranges for each direction of movement were as defined by Kuhlman (1993) and are presented in

Appendix VI. Any participant with range of movement less than the study defined "normal" was excluded from further participation.

*Cervical Range of Movement device; Performance Attainment Associates. 958 Lydia Drive, Roseville, MN 55113.

Figure 4A.1. The CROM

Figure 4A.2 The CROM – side view

Head activity

Participants completed the HAT according to the protocol (see Appendix I). Their performances were recorded on video. The video recorder was situated directly in front of the seated participant with the lens set to approximately eye level. The video recorder was switched on prior to the start of the data collection and a remote control device was used to pause the recording between tasks. For the eating and forward reach tasks the camera position was moved, and recordings were taken from the participant's non-dominant side.

Seated forward and lateral reach

A single seated forward and lateral reach in sitting (see figures 4A.3 and 4A.4) was recorded for each participant. The distance reached during the seated forward and lateral reaches of the HAT was measured using a height-adjustable portable metre rule. The metre rule was adjusted to acromion height. Participants were asked to make a fist and to extend their dominant arm in line with the ruler. Measurement of the starting position was taken from the proximal inter-phalangeal joint of the third finger along the metre rule. Participants were requested to look at the yellow light (situated at eye level 1.5m in front), throughout the reach. Participants were then asked to reach as far (forwards or to the side) as they could without losing balance. A measurement of the proximal inter-phalangeal joint of the third finger along the metre rule was taken at the point of maximum reach. Distance reached was calculated as the difference between the start and maximum reach measurement. Patients were given one practice attempt in each direction prior to starting the HAT.

Figure 4A.3 Seated forward reach

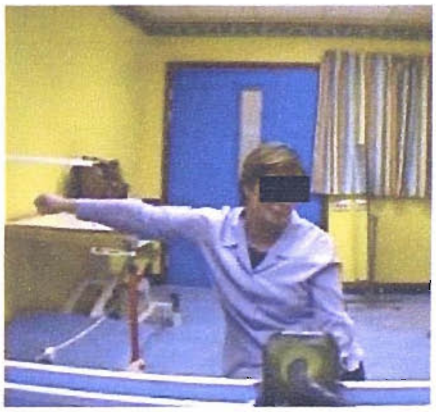

Figure 4A.4 Seated lateral reach

Head activity interview

A short interview was conducted following the schedule presented in Appendix IIB. Whether participants had experienced any of the following symptoms was ascertained:

- Difficulty moving the head
- Difficulty seeing things around them
- Visual or hearing problems
- The presence of neck or shoulder pain or headaches
- Episodes of dizziness
- Difficulties with balance

4A.2.4 Data analysis

Data were analysed using SPSS 11.5 for Windows. Non-parametric statistics were used, as the data were not normally distributed and the sample size was small. Assessment one:

- The HAT data were summarised and cross-tabulation used to illustrate the relationship between head and trunk strategies used in the tasks.
- Seated reach data were summarised, and summary statistics presented with inter-quartile ranges to show the spread of values around the median.
- Responses to the interview questions were collated and summarised.
- HAT data from the participants assessed on all three occasions were summarised, and any change in score explored.

4A.3 Results

4A.3.1 Characteristics of the sample

Twenty subjects were recruited to the study. The sample comprised 14 women and six men. The median age of the subjects was 49 with a range from 40 to 72. All subject were right handed. The characteristics of the sample are presented in table 4A.1.

Variable	Value	Sample	Men	Women
Gender	M: F	6:14		
Age (years)	Median (min-max)	49 (40-72)	42 (40-52)	49 (40-72)

Table 4A.1 Healthy adult sample characteristics

4A.3.2 Assessment one

4A.3.2.a Cervical spine range of movement

All participants had active range of movement within the "normal" range as defined by Kuhlman (1993) (see Appendix VI).

4A.3.2.b Head activity as rated by the HAT

<u>4A.3.2.b.i Total HAT score</u>

Total HAT scores ranged from eight to ten (score range = 0-10), with a median score of ten. Seventeen of the twenty participants scored the maximum HAT score of ten. Participants scored the maximum score for all tasks except the reaching task. For the reaching task seventeen patients scored the maximum score of two, two participants scored one, and one participant scored zero.

4A.3.2.b.ii Category ratings for each task

The results of the tool item category ratings are presented for each task in the following five sections.

Upright sitting task

All 20 participants scored the maximum score of four on the upright sitting task; all were rated as attempting to correct their posture through the use of selective movement; all achieved an upright head and trunk position, and all were able to maintain the upright position for at least ten seconds. The results for the Upright sitting task are presented in table 4A.2.

Tool item	Rating category	N=20
Attempt to correct	Yes	20
	No	0
Selective Movement	Yes	20
	No	0
Trunk upright	Yes	20
	No	0
Head upright	Yes	20
	No	0
Head position	Flexion	0
	Extension/protraction	0
	Right side flexion	0
	Left side flexion	0
	Right rotation	0
	Left rotation	0
	Not applicable	20
Upright maintained	Yes	20
	No	0
	Not applicable	0

4A.2 Upright sitting task results

Visual search task

All participants scored a maximum score of one on the visual search task. All were rated as turning their heads to both left and right whilst searching. Half the participants (10) moved their trunks whilst searching. Of the participants that moved their trunks whilst searching, all were rated as moving their heads and trunks freely. The results for the Visual search task are presented in table 4A.3.

Tool item	Rating category	N=20
Search strategy	Both ways	20
	One way	0
	Incomplete search	0
Trunk movement	Yes	10
	No	10
Trunk movement quality	Freely	10
	Rigid	0

Table 4A.3 Visual search task results

Communication task

All participants scored a maximum score of two on the communication task. With the interviewer sitting on the participant's right 13 participants were rated as varying the orientation of their heads throughout the conversation ("towards & away"), and the remaining seven participants were rated as orientating their heads "towards" the interviewer. With the interviewer on the participant's left 15 used the "towards & away" strategy and five participants orientated their heads "towards" the interviewer. All participants used their heads for gestures during conversation. With the interviewer to the participant's right 10 participants used frequent and large gestures and nine used moderate gestures, with only one subject using minimal and small gestures. With the interviewer to the left of the participant 12 subjects used frequent and large gestures, seven used moderate gestures, and again only one subject used minimal and small gestures. The results for the Communication task are presented in table 4A.4.

Tool item	**Rating category**	**N=20**
Orientation head (R)	Away	0
	Towards	7
	Towards and away	13
Orientation head (L)	Away	0
	Towards	5
	Towards and away	15
Head gestures (R)	Yes	20
	No	0
Head gestures (L)	Yes	20
	No	0
Gesture size (R)	Frequent & large	10
	Moderate	9
	Minimal & small	1
Gesture size (L)	Frequent & large	12
	Moderate	7
	Minimal & small	1

Table 4A.4. Communication task results

Cross-tabulation of the results was used to explore the different head activity strategies used by individual participants when communicating to the left and right. Only four subjects showed a difference in head orientation between sides (see table 4A.5). Orientation of the head to the interviewer on the right was significantly associated with orientation to the left (Fisher's Exact Test P=.0031).

		Orientation (left)	
		Towards	Towards & away
Orientation (right)	Towards	4	3
	Towards & away	1	12

Table 4A.5. Comparison of head orientation between sides

The only subject to use minimal and small gestures did so to both sides. Four participants showed a difference in gesture size and frequency between sides (see table 4A.6). Size and frequency of gesture use to the right was significantly associated with that to the left (Pearson Chi-Square P= <0.001).

		Gesture size (left)		
		Frequent & large	Moderate	Minimal & small
Gesture size (right)	Frequent & large	9	1	0
	Moderate	3	6	0
	Minimal & small	0	0	1

Table 4A.6 Comparison of gesture use between sides

Eating task

All participants scored a maximum score of one on the eating task. All were rated as using the "meet in the middle" feeding action, with the food entering the mouth through the use of a coordinated head, trunk, and upper-limb movement. The results for the eating task are presented in table 4A.7.

Tool item	Rating category	N=20
Feeding action	Arm only	0
	Meet in the middle	20
	Head to pot	0

Table 4A.7 Eating task results

Reaching task

Seventeen of the twenty participants scored the maximum score of two on the reaching task, two scored one, and one scored zero. Eighteen participants demonstrated a head counterbalancing movement (head extension accompanying trunk flexion) on reaching forwards. On reaching to the side, 18 participants demonstrated a head counterbalancing movement (head side-flexion in the opposite direction of the reach). The results for the eating task are presented in table 4A.8.

Tool item	Rating category	N=19
Forward reach righting reaction	Yes	18
	No	2
Lateral reach righting reaction	Yes	18
	No	2

Table 4A.8 Reaching task results

Cross tabulating the results from the forward and lateral reaching tasks revealed that, of the two subjects not demonstrating head counterbalancing on reaching forward, one did not use head counterbalancing on reaching to the side (see table 4A.9).

		Lateral reach Head counterbalancing	
		No	Yes
Forward reach Head counterbalancing	No	1	1
	Yes	1	17

Table 4A.9 Comparison between forward and lateral reaches

4A.3.2.c Seated forward and lateral reach

The median distance reached forwards for the whole sample was 46cm, with a range from 33cm-60cm. The median distance reached to the side for the whole sample was 35cm, with a range from 24cm-44cm. Dividing the sample into men and women revealed a greater distance reached by men in both directions. The median distance reached forwards for the men was 57cm, and for the women was 42cm. The median distance reached to the side for the men was 41cm, and for the women was 33cm. Summary statistics for the forward and lateral seated reaches are presented in table 4A.10.

Distance reached (cm)		Whole sample N=20	Men N=6	Women N=14
Forward reach	Median (min-max)	46 (33-60)	57 (52-60)	42 (33-53)
	IQR	40-53	53-60	39-48
Lateral reach	Median (min-max)	35 (24-44)	41 (33-44)	33 (24-42)
	IQR	31-39	35-44	30-37

Table 4A.10 Seated distance reached by the healthy adult sample

The difference between men and women in the distance reached both forward and to the side was significant (P=.0005 forward reach; P=.0045 lateral reach). The distance reached forwards was consistently greater than that reached to the side for each participant. Forward reach distance was positively correlated with lateral reach distance, with a significant increase in distance reached laterally with increasing distance reached forward (r=0.65, P=.0006). Age was negatively correlated with forward reach distance, with a significant reduction in distance reached with increasing age (r=-0.533, P=.0033). The trend to decreasing distance reached with increasing age was also found for lateral reach but the correlation was not significant (r=-0.219, P=.0614).

4A.3.3 Repeated assessments

4A.3.3.a Sample

Eight subjects agreed to repeat the assessment on a further two occasions. This sub-sample comprised seven women and one man. The median age of the subjects was 50 with a range from 40 to 72. The characteristics of the sub-sample participating in repeated assessments are presented in table 4A.11.

Variable	Value	Sample
Gender	M: F	1:7
Age (years)	Median (min-max)	50 (40-72)

Table 4A.11 Repeated assessment sub-sample characteristics

All participants completed all three assessments, each two weeks apart.

4A.3.3.b Cervical spine range of motion

All participants had cervical spine range of movement within the study defined as "normal" (see Section 4A.2.3.c.i) on all three assessments.

4A.3.3.c Head activity as rated by the HAT

4A.3.3.c.i Total HAT scores

Total HAT scores ranged from eight to ten for all three assessments with a median score of ten. No participant had a change in total HAT score between any of the three assessments.

4A.3.3.c.ii Category ratings for each task

The results of the tool item category ratings for the repeated assessments are presented for each task in turn.

Upright sitting task

There was no change in score for any of the tool item categories for the upright sitting task between the three assessments. All participants consistently demonstrated attempting to correct using selective movement, achieving an upright head and trunk position, and maintaining the upright position for ten seconds.

Visual search task

There was no change in score for the visual search task between the three assessments, but some participants demonstrated a different movement pattern for the non-scored tool item 'search strategy'. All participants consistently demonstrated a search both ways. Four participants used their trunks to search on all three occasions. The remaining four participants did not use their trunks to search on assessment one. Two of these participants continued not to use their trunks for assessments two and three, while the remaining two changed to using their trunks on assessment two, and continued to do so on assessment three. All participants using their trunks demonstrated head and trunk moving "freely".

Communication task

There was no change in score for the communication task between the three assessments, but some participants demonstrated different movement patterns for the non-scored tool items 'orientation of the head', and 'gesture size and frequency'. Three of the participants used the varied head orientation (" towards and away") to both sides on all three assessments, and the remaining five used either " towards and away" or "towards". Three of the participants used "moderate" gesture size and frequency to both sides on all three assessments, and the remaining five used either "moderate" or "frequent and large". Only one participant used the same orientation and gesture size for all three assessments.

Eating task

There was no change in score for any of the tool item categories for the eating task between the three assessments. All participants consistently demonstrated a "meet in the middle" feeding action.

Reaching task

There was no change in score for any of the tool item categories for the reaching task between the three assessments. Seven of the participants consistently demonstrated a head counterbalancing reaction for both the forward and lateral reach. The remaining patient demonstrated no counterbalancing reaction for either reach on all three occasions.

4A.3.3.d Seated forward and lateral reach

The median distance reached forwards on assessment one was 40.5cm, with a range from 35cm-55cm. On assessments two and three the median forward reach was 40 cm, with a range from 36-55 and 36-52 respectively. No participant varied more than 3cm between all three forward reaches. The median distance reached to the side on assessment one was 33cm, with a range from 24cm-42cm. The median distance reached to the side at assessment two was 32.5cm and at assessment three was 32 cm. Again no participant varied more than 3cm between all three lateral reaches. Summary statistics for the forward and lateral seated reaches for all three assessments are presented in table 4A.12.

Distance reached (cm)		**Assessment 1**	**Assessment 2**	**Assessment 3**
Forward reach	Median (min-max)	40.5 (35-55)	40 (36-55)	40 (36-52)
Lateral reach	Median (min-max)	33 (24-42)	32.5 (27-40)	32 (25-39)

Table 4A.12 Repeated assessments seated distance reached

4A.3.4 Summary of findings

4A.3.4.a Assessment one

Cervical spine range of movement

- All Healthy adult participants had active cervical spine movement within the study defined "normal" range

Head activity

- Total HAT scores ranged from eight to ten, with a median HAT score of ten. Failure to demonstrate head counterbalancing on the reaching task accounted for all dropped HAT scores.
- The distribution of categories of head activity demonstrated by healthy adults showed a tendency towards a "typical" pattern. Variation among categories was only present for un-scored tool items and there was a trend to be within adjoining categories.

Seated reach

- All participants reached greater distances forwards than to the side.
- Distance reached forwards was positively correlated to distance reached to the side.
- Men reached significantly further than women, both forwards and to the side.
- Age was negatively correlated with forward reach distance but no significant correlation was found for lateral reach.

Head activity interview

- All of the participants reported no difficulty moving their heads, no difficulty seeing things around them, or had experienced any recent episodes of dizziness, headaches or neck pain.

4A.3.4.b Repeated assessments

Head activity

- There was no change in total HAT score for any participant between assessments. Total HAT scores ranged from eight to ten, with a median HAT score of ten.
- Differences in the movement patterns for some non-scored tool items were demonstrated during the visual search and the communication task. Differences were between adjacent categories only.

Head activity interview

- All participants consistently reported an absence of difficulty moving their heads, difficulty seeing things around them, and that no episodes of dizziness, headaches or neck pain had been experienced during the four-week assessment period.

4A.4 Conducting and analysing the HAT

The HAT test protocol worked well, with all participants carrying out the instructions for each of the five tasks in the intended manner. It was feasible to conduct the HAT in a small private space, in line with that available in most clinical settings. No safety issues arose when using the HAT in this study. There were no adverse incidents to report, and none of the participants reported anxiety about the test, or any pain or fatigue whilst completing the HAT.

The time required to analyse each participant's HAT performance highlighted that the test would require simplification before it was appropriate for use in routine clinical practice. With the test in its current form, the use of repeat viewing during analysis necessitates the video recording of HAT performances.

It is possible that the new assessment tool protocol worked well because of the nature of the sample with which it was used. The HAT was designed specifically for use with patients following acute stroke and undertaking the HAT with this population is likely to give rise to a unique set of problems not encountered with a sample of healthy (if older), adults. Probably enhancing the smoothness of its first use was that the developing researcher was the assessor. To be confident that the test is workable, the HAT would also need to be tested by different assessors.

This study provided further testing of the HAT prior to its use on a sample of patients with acute stroke. The true suitability of the HAT protocol, however, will only be truly tested when it is used with the population for whom it was developed.

The findings of this investigation will be discussed (see Section 4.C.1) in light of the findings from the study presented in the following section (4B), where the head activity used by a sample of patients with acute stroke is described and explored.

Section 4B

Head activity used by patients in the first six weeks following acute stroke

4B.1 Introduction

The development of the HAT was described in Chapter 2. In Sections 3A and 3B the external validity and acceptable reliability of the HAT was demonstrated. The HAT proved a safe and workable assessment tool. It was now possible to use the new tool in the clinical setting to describe the head activity used by patients in the first six weeks following first-ever acute stroke.

4B.1.1 Aims of the study

i. To describe the head activity used by patients with first-ever acute stroke.
ii. To gain an understanding into the patient's perspective of any difficulty with head activity experienced following stroke.
iii. To identify any relationships between head activity and classification of stroke, ADL ability, level of motor and sensory impairment, balance, and the presence of neglect.
iv. To profile the changes in head activity during the first six weeks following acute stroke.

4B.2 Methods

4B.2.1 Study design

This study was a prospective observational investigation of a hospital-based sample of patients with acute stroke.

4B.2.2 Sample

The sample source was consecutively admitted patients to Christchurch Hospital Stroke Rehabilitation Unit. Recruitment took place over a 107-day period from June-October 2003.

4B.2.2.a Inclusion criteria:

Patients were included if they:

- Had a diagnosis of first-ever stroke
- Were medically stable
- Scored at least eight on the Abbreviated Mini-Mental Test (Hodkinson 1972)
- Had given informed consent

4B.2.2.b Exclusion criteria:

Patients were excluded if they had a:

- History of other neurological condition
- History of previous stroke
- History of vestibular dysfunction or other balance disorder
- Severe cervical spine dysfunction
- Pre-existing visual impairment not corrected for by glasses
- Score of less than eight on the Abbreviated Mini-Mental Test

4B.2.3 Procedures

4B.2.3.a Ethical approval

Permission to conduct the study was granted by the Local Research Ethics Committee and The Royal Bournemouth and Christchurch Hospitals NHS Trust (see Appendix VII c & d).

4B.2.3.b Recruitment

Potential recruits were identified via the medical records held on the Stroke Rehabilitation Unit. Patients who fulfilled the inclusion criteria were approached in person by the researcher. The study was explained to the patient, and an information sheet given inviting their participation. Patients were encouraged to discuss taking part with relatives and friends if they wished. Patients were revisited by the researcher within 48 hours, and asked whether or not they wished to take part in the study. Written informed consent was obtained from patients agreeing to take part.

4B.2.3.c Assessments

Patients were assessed on up to three occasions whilst in-patients on the Stroke Rehabilitation Unit. Assessments took place at the end of the first, third and sixth week following stroke. Patients discharged or transferred prior to six weeks were not followed up, as the equipment required for the study prevented patients from being assessed in their own homes. Patients admitted to the Stroke Unit after the first week following stroke were not excluded from the study. Basic demographic data of age, gender, dominant hand, date of stroke, OCSP classification of stroke, and the presence of visual, speech, and swallow impairment were recorded at assessment one.

4B.2.3.c.i Measures

The following measures were included in the study and were undertaken at each assessment:

- Assessment of cervical spine range of movement
- The HAT
- Seated forward and lateral reach
- Head activity interview
- Barthel ADL Index (Mahoney and Barthel, 1965)
- Rivermead Motor Assessment (Lincoln and Leadbitter, 1979)
- Achievement of mobility milestones (Smith and Baer, 1999)
- Berg Balance Scale (Berg et al., 1989)
- Nottingham Sensory Assessment Scale (Lincoln et al., 1998)
- Behavioural Inattention Test (Wilson et al., 1987)

Measurement of cervical range of movement

Cervical range of movement was measured using the CROM (as described in Section 4A). Active and passive range of flexion, extension, side flexion, and rotation were assessed as being within the "normal" range for this age group or not. The "normal" ranges for each direction of movement were as defined by Kuhlman (1993) and are presented in Appendix VI. Range of movement was measured in supported sitting. Active range of movement was assessed first, only when active range was less than the " normal" range was passive range tested.

The HAT

Patients completed the HAT according to the protocol (Appendix I). Their performance was recorded on video. The video recorder was situated directly in front of the seated participant with the lens set to approximately eye level. The video recorder was switched on prior to the start of the data collection and a remote control device was used to pause the recording between tasks. For the eating and forward reach tasks, video recordings were taken from the side. The camera was moved to the side of the patient, contra-lateral to the arm with which they were to reach.

Seated forward and lateral reach

The distance reached during the seated forward and lateral reaches of the HAT was measured using a height-adjustable portable metre rule. The metre rule was adjusted to acromion height. Subjects were asked to make a fist and to extend their arm in line with the ruler. Measurement of the starting position was taken from the proximal inter-phalangeal joint of the third finger along the metre rule. Participants were then asked to reach as far (forwards or to the side) as they could without losing balance. A measurement of the proximal inter-phalangeal joint of the third finger along the metre rule was taken at the point of maximum reach. A single reach in each direction was measured. Distance reached was calculated as the difference between the start and reach measurement. Patients were given one practice attempt in each direction prior to starting the HAT.

Head activity interview

A short interview was conducted following the schedule presented in Appendix IIa. Whether patients had experienced any of the following symptoms since their stroke (assessment 1), or previous assessment (assessments 2 and 3) was ascertained:

- Difficulty in moving their head
- Difficulties seeing things around them
- Changes in vision or hearing
- The presence of neck or shoulder pain or headaches
- Episodes of dizziness
- Difficulties with balance

The Barthel Index

ADL ability was assessed using the Barthel ADL Index. The scale covers the ten most common areas included within ADL scales and specifically covers continence of bowels and bladder. The Barthel Index is simple to use and is scored from zero to 20. A low score predicts a reduced likelihood of discharge home, and a lower level of social, domestic and leisure activities. The validity and reliability of the Barthel Index have been established. The sensitivity of the Barthel index is, however, limited in two ways: Firstly it has a definite floor and ceiling effect, and secondly it is insensitive to small changes. For these reasons the Barthel Index has been used in conjunction with the battery of other measures.

The Rivermead Motor Assessment

The Rivermead Motor Assessment comprises three sections: gross function, leg and trunk, and arm. The gross function section was devised to measure motor function. The leg and trunk, and the arm section were each devised to measure both functional movement and control. The gross function section consists of 13 items, the leg and trunk section 10 items, and the arm section 15 items. The Rivermead Motor Assessment is 'Guttmann scaled' forming a hierarchy with identical scores in patients indicating the same level of impairment. Patients able to complete an item score one, and patients unable to complete an item score zero. Assessment for an item was stopped after three failed attempts. Higher scores indicate better functional movement and a greater level of control.

The achievement of mobility milestones

The achievement of mobility milestones was used as a measure of functional mobility. Four milestones were measured: one-minute sitting balance, 10-second standing balance, 10 steps, and 10-metre walk. Whether or not the milestone had been achieved at the time of the assessment was rated.

The Berg Balance Scale

The Berg Balance Scale was used as a measure of balance. The scale consists of 14 items including functional balance tasks such as standing, transfers, stepping, turning and reaching. Eight of the items are timed. Each item is scored from zero to four, with a maximum total score of 56. A higher score indicates less impaired balance.

Berg et al. (1992) recommend a cut-off score of 45, indicating that subjects scoring below 45 are in need of supervision or assistance, whilst those scoring above are safe in independent ambulation.

The Nottingham Sensory Assessment Scale

Three sub-tests of the Nottingham Sensory Assessment Scale – light touch, pressure, and kinaesthetic tests – were used as a measure of sensory impairment. To test light touch and pressure the patient was seated and blindfolded. Light touch was tested by touching the skin with a cotton wool ball, and pressure by pressing the skin with the index finger just enough to deform the skin contour. The patient was asked to verbally indicate when they felt the sensation. First the unaffected side was tested for light touch. If this was normal only the affected side was tested. The affected side was then tested for both light touch and pressure. Each part of the body was assessed three times for each test. For each section of the test, face, the hand, wrist, ankle, and foot were assessed first. If sensation was intact in these areas full scores were awarded for the more proximal areas of the upper (elbow, shoulder, and trunk) and lower (knee and hip) limb respectively. Scores ranged from zero to two; 0=absent sensation on all three occasions, 1= identifies test sensation but not on all three occasions, and 2= correctly identifies the test sensation on all three occasions. To test kinaesthetic sensations, appreciation of movement, its direction, and joint position sense were assessed simultaneously. The upper limb was tested with the patient sitting, the lower limb with the patient in supine. Three practice movements were carried out prior to blindfolding. The affected limb was supported and moved (by the researcher) in various directions with movement at a single joint only at any one time. The patient was asked to mirror the movement with the other limb. The test was repeated on the other side if the patient had good recovery of the affected limb. Again the more distal joints were tested first; if a maximum score was achieved full marks to the more proximal joints of the corresponding limb were awarded. Scores ranged from zero to three; 0= no appreciation of movement, 1= movement appreciation but direction incorrect, 2=movement and direction mirrored but new position is inaccurate, 3= accurately mirrors the test movement.

The Behavioural Inattention Test

The conventional sub-tests of the Behavioural Inattention Test were used to assess the presence of unilateral visual neglect. The six conventional sub-tests are line crossing, letter cancellation, star cancellation, figure and shape copying, line bisection and representational drawing, each being a simple pencil and paper test. In each sub-test the number of omissions was recorded. The maximum total score is 146. Wilson et al. (1987) suggest a cut-off score of 129, with a score of 129 or below indicating the presence of unilateral visual neglect.

4B.2.4 Data Analysis

Data were analysed using SPSS 11.5 for Windows. Non-parametric statistical methods were used as there was a non-normal distribution of the data and the sample size was small.

4B.2.4.a Assessment one

- The data from patients assessed at assessment one were summarised and summary statistics are presented with inter-quartile ranges to show the spread of values around the median.
- The HAT data were summarised and cross-tabulation is used to illustrate the relationship between the head and trunk strategies both within and between tasks.
- The responses to the interview questions about head activity were collated and summarised.
- Mann Whitney U tests were performed to compare:
  - The head activity used by patients reporting, and those not reporting, difficulty in moving their head.
  - The head activity used by patients with more severe stroke (as defined by OCSP classification), and those with less severe stroke.
- Spearman's rank correlation coefficients were calculated to measure the strength of the association between HAT score and ADL ability, motor impairment, balance, sensory impairment, and level of neglect.

4B.2.4.b Change over time – Assessments one to three

- The data of patients assessed at all three assessments were summarised and summary statistics are presented with inter-quartile ranges to show the spread of values around the median.
- The presence of any change in scores between assessments one and three was explored using the Freidman Test.
- Further exploration of the change in scores between each assessment (assessments one and two, and two and three) was undertaken using Wilcoxon Signed Rank test.
- Mann Whitney U tests were performed to compare:
    - The functional outcome at six weeks of those with a low and those with a high initial HAT score
    - The HAT score at six weeks of those with a low and those with a high initial HAT score

4B.3 Results

The findings will be presented under the following headings:

- Recruitment
- Characteristics of the whole sample
- Assessment one
    - Sample
    - Patient characteristics
    - Head activity
    - Patient perception of head activity
    - Relationship between head activity and classification of stroke
    - Associations between head activity and function
    - Summary of findings
- Change over time – Assessments one to three
    - Sample
    - Patient characteristics
    - Change in function from assessment one to three
    - Changes in head activity from assessment one to three

- Change in perception of head activity from assessment one to three
    - Relationship between initial HAT scores and outcome at six weeks
    - Summary of findings
- Individual patient profiles

4B.3.1 Recruitment

Sixty-four patients were admitted to the stroke unit during the recruitment period. Thirty patients met the study inclusion criteria, of whom five declined to participate and nine failed the cognitive screening test. The remaining sixteen patients were recruited to the study. An outline of the response and consent rates is shown in figure 4B.1.

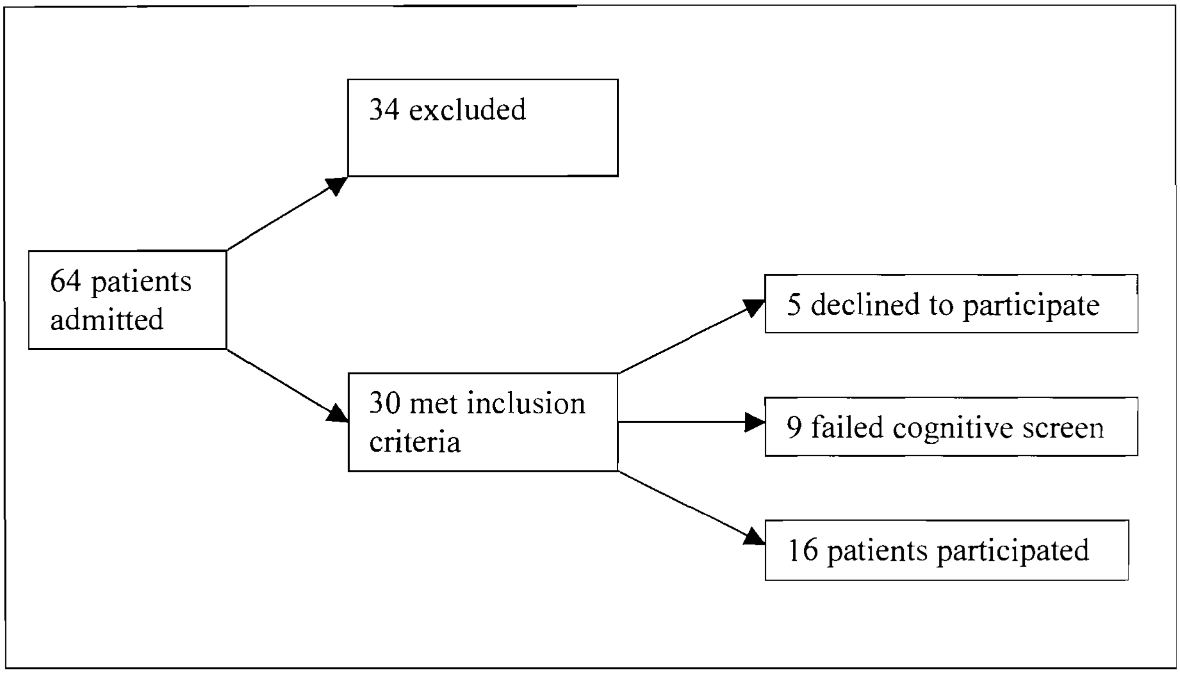

Figure 4B.1 Recruitment of the patient sample

Of the sixteen patients recruited to the study 15 were assessed at the end of the first week (assessment 1), one patient not being admitted until 10 days following stroke. Thirteen of the patients were assessed at assessment 2, with two patients having been discharged home, and one transferred to an acute medical ward. By the third assessment, ten of the patients remained on the stroke unit, a further three having been discharged home. Table 4B.1 summarises the patients' admissions and discharges in relation to the assessment timings.

Patient	Assessment 1	Assessment 2	Assessment 3
1	√	X T/F	X T/F
2	√	√	√
3	√	√	√
4	√	√	X D/CH
5	√	X D/CH	X D/CH
6	√	√	√
7	√	√	√
8	√	√	√
9	√	√	X D/CH
10	√	√	X D/CH
11	√	X D/CH	X D/CH
12	√	√	√
13	√	√	√
14	√	√	√
15	√	√	√
16	X N/A	√	√

Key:
√ = Assessment completed
X= Assessment not undertaken
T/F= transferred
D/CH= discharged
N/A= not admitted

Table 4B.1 Profile of patients completing assessments

The median number of days since stroke for the first assessment was eight with a range from seven to 11. For the second assessment the median number of days since stroke was 21 with a range of 18-26 and for the third the median was 41 days since stroke with a range from 36 to 43. The timings of the assessments and the number of patients completing them are summarised in table 4B.2.

	Assessment 1	Assessment 2	Assessment 3
No. of days since stroke Median (min-max)	8 (7-11)	21 (18-26)	41 (36-43)
No. of patients completing assessment	15	13	10

Table 4B.2 Patient assessment timings

4B.3.2 Characteristics of the whole sample

The 16 patients comprised 11 men (69%) and five women (31%). All patients scored eight or higher on the Abbreviated Mini-Mental Test used as a cognitive screening test; a minimum score of eight was required to participate. Basic demographic data are presented in table 4B.3. The median age of the patients was 76 with a range from 57-84. Twelve patients had a right hemisphere infarct and four had a left hemisphere infarct. One patient had a TACI, two had a PACI, three a POCI, and seven had a LACI; the remaining three had PICH.

Gender	Age	Hemisphere of stroke	Classification of stroke
Male 11 Female 5	Median 76 min-max 57-84	R= 12 L= 4	TACI= 1 PACI= 2 POCI= 3 LACI= 7 PICH= 3

Table 4B.3 Patient basic demographic data

4B.3.3 Assessment One

4B.3.3.a Sample

Fifteen patients were assessed at assessment one. The median number of days since stroke was eight with a range from seven to 11 (see table 4B.2).

4B.3.3.b Patient characteristics

4B.3.3.b.i ADL ability, motor impairment, mobility and balance

Summary statistics for the measures of ADL ability, motor impairment, mobility and balance at assessment one are presented in table 4B.4.

	Median	Min-max	IQR
Barthel Index	9	1-16	6-13
Rivermead Motor Assessment			
Gross Function	3	0-5	1-5
Leg and Trunk	3	0-5	2-5
Arm	5	0-13	1-10
Berg Balance Scale	9	0-33	4-30
Achievement of Mobility Milestones			
	Yes : NO	Yes % : N0 %	
One minute sitting balance	14 : 1	93 : 7	
Standing	7 : 8	47 : 53	
Stepping	2 : 13	13 : 87	
10m walk	0 : 15	0 : 100	

Table 4B.4 Assessment one ADL ability, motor impairment, mobility, and balance scores

A large range in Barthel Index, Rivermead Motor Assessment, and Berg Balance Scale scores was evident. The Barthel Index scores ranged from one to 16 with all patients having some impairment in their ADL ability. Rivermead Motor Assessment scores for gross function ranged from zero to five, and for leg and trunk from zero to seven. There was a larger range of scores in the arm section with a range from zero to thirteen. Berg Balance Scale scores ranged from zero to 33. When assessed for the achievement of mobility milestones all but one patient had achieved one minute sitting balance, and half were able to stand unsupported. Only two patients were able to take ten steps, and none could walk ten metres. The scores from the above measures indicated that the sample presented with moderate to severe levels of disability at the first assessment.

4B.3.3.b.ii Distance reached

The distances reached for the seated forward and lateral reach are presented in table 4B.5. There was a large range in scores for both directions of reach. The patient without independent sitting balance was scored as reaching zero cm for each reach. Distances reached forward were greater than those reached to the side for all subjects. Forward reach distances ranged from 0cm to 47cm with a median of 33cm. The distance reached to the side ranged from 0cm to 30cm with a median of 14cm.

	Median	Min-max	IQR
Forward reach (cm)	33	0-47	18-37
Lateral reach (cm)	14	0-30	8-22

Table 4B.5 Assessment one seated distance reached

4B.3.3.b.iii Sensation and unilateral visual neglect

The scores for sensory impairment and unilateral neglect are shown in table 4B.6. Again, a large range in scores is evident. Using a score of 129 as the cut-off for the presence of unilateral neglect, two patients (patients 1 and 3) had neglect at assessment one.

	Median	Min-Max	IQR
Nottingham Sensory Assessment Score	54	26-64	32-64
Behavioral Inattention Test	141	103-146	134-145

Table 4B.6. Assessment one sensation and unilateral neglect score

4B.3.3.c Head activity

4B.3.3.c.i Cervical spine range of movement

Only two patients had active range of movement less than the study definition of "normal range" for any of the directions of movement at the first assessment. All directions of active movement for one patient (patient no.1) were less than "normal" but all passive ranges were within the "normal" range (study defined "normal" ranges are presented in Appendix VI). At the time of assessment the researcher noted a general reluctance by the patient to move the head. The other patient with reduced range (patient no. 14) had an active range of cervical extension of 22°, approximately half of the study-defined normal. Passive range was also less than "normal" and was equal to the active range. The patient was unaware of the limitation in range and reported no discomfort on movement.

4B.3.3.c.ii Head position and movement (as rated by the HAT)

HAT score

Total HAT scores at assessment one are available for 14 of the 15 patients; patient 8 refused to be recorded on video and was therefore excluded from the HAT scoring and rating. A breakdown of HAT scores for each task, and ratings for individual tool items were completed for 13 patients. Patient number 3 was unable to complete the HAT due to the absence of one-minute independent sitting balance; a total score of zero was awarded but ratings of head activity for individual tasks were omitted. Total HAT scores ranged from 0-10 with a median score of 5.5. Within each task the scores ranged from the minimum to the maximum score. A breakdown of individual patients' total HAT scores showing the scores for each task are shown in table 4B.7.

Pt no.	HAT task and score range					
	Upright sitting 0-4	Visual search 0-1	Communication 0-2	Eating 0-1	Reaching 0-2	Total 0-10
1	0	0	0	0	0	0
2	0	1	2	1	0	4
3	Patient unable to sit unsupported					0
4	1	1	2	1	0	5
5	4	1	2	1	1	9
6	4	1	2	1	0	8
7	4	1	2	1	1	9
8	Refused to be recorded on video					
9	4	1	2	1	1	9
10	0	1	2	1	1	5
11	4	1	2	1	2	10
12	2	1	2	1	0	6
13	1	1	2	0	2	6
14	0	1	2	1	0	4
15	0	1	2	1	0	4
16	Not admitted					

Table 4B.7 Assessment one HAT scores

Category ratings for each task

Tool items ratings for each of the tasks are shown in tables 4B.8-4B.12.

Upright Sitting

All but one of the thirteen patients attempted to correct their posture (patient no.14). Of the twelve patients who attempted to correct their posture five were rated as not using selective movement. Eight patients achieved an upright trunk but only five achieved an upright head position. All the patients who achieved an upright head and trunk posture were able to maintain it for ten seconds. A summary of the results for the 'upright sitting' task are presented in table 4B.8.

Attempt to correct	Yes No	12 1
Selective movement	Yes No Not applicable	7 5 1
Trunk upright	Yes No	8 5
Head upright	Yes No	5 8
Head position	Flexion Extension/protraction Right side flexion Left side flexion Right rotation Left rotation Not applicable	0 1 2 1 2 2 5
Maintained	Yes No Not applicable	5 0 8

Table 4B.8. Assessment one HAT results for upright sitting task

Visual Search

All but one patient searched to both their left and right (patient no.1). Eleven patients moved their trunk while searching, of which three were rated as moving their head and trunk in a rigid manner. A summary of the results for the 'visual search' task is presented in table 4B.9.

Search strategy	Both ways One way	12 1
Trunk Movement	Yes No	11 2
Quality of head and trunk movement	Move freely Rigid	8 3

Table 4B.9 Assessment one HAT results for visual search task

Communication

All patients orientated their heads towards, or used a mixed orientation including towards, when communicating with the researcher to the right. When communicating with the researcher to the left, one patient (patient no. 1), looked away continuously. All patients used their heads to gesture when communicating with the researcher to their right. All but one used their head to gesture when communicating with the researcher to their left. Patients used all categories of gesture size to both sides with moderate being used most frequently, and frequent and large least often. A summary of the results for the 'communication' task is presented in table 4B.10.

Orientation of head Right	Away Towards Towards and away	0 3 10
Orientation of head left	Away Towards Towards and away	1 3 9
Uses head for gesture Right	Yes No	13 0
Uses head for gesture Left	Yes No	12 1
Size of head gesture right	Frequent and Large Moderate Minimal and small	3 7 3
Size of head gesture left	Frequent and Large Moderate Minimal and small	1 8 3

Table 4B.10 Assessment one HAT results for communication task

Eating

Eleven of the thirteen patients used the feeding action where hand and mouth meet in the middle. The remaining two patients (patient nos. 1 & 13) used only an arm movement with the head remaining still. A summary of the results for the 'eating' task is presented in table 4B.11.

Feeding action	Meet in the middle Arm only Head to pot	11 2 0

Table 4B.11 Assessment one HAT results for eating task

Reaching

Approximately half of the patients were rated as demonstrating a counterbalancing reaction with their head during the forwards reach. Only two out of the thirteen patients demonstrated a counterbalancing reaction with their head during the lateral reach (patient nos. 11 & 13). A summary of the results for the 'reaching' task is presented in table 4B.12.

Counter balance with head on forward reach	Yes No	6 7
Counter balance with head on lateral reach	Yes No	2 11

Table 4B.12 Assessment one HAT results for eating task

4B.3.3.c.iii Is there a relationship between the head and trunk strategies used both within and between tasks?

The question arises as to whether those who scored poorly on one of the HAT items also had a low score on other tool items. The presence of a relationship was explored by cross-tabulating the data from the relevant tool items. Further statistical analysis was not undertaken due to the small sample size and spread of the data.

In exploring the relationship between 'upright head' and 'upright trunk' in the sitting task it was apparent that all the patients who failed to achieve an upright trunk also failed to achieve an upright head, as shown in red in table 4.13. In other words, none of the patients demonstrated a righting reaction of the head on the trunk to bring the head to an upright position to compensate for a non-upright trunk. The patient who made no attempt to correct the posture (patient no. 14) was rated as having neither an upright head nor trunk.

		Head upright		
		No	Yes	
Trunk upright	No	5	0	5
	Yes	3	5	8
		8	5	13

Table 4B.13 Cross-tabs of HAT tool items "upright head" and "upright trunk"

The relationship between 'rigid' pattern of head and trunk movement during the visual search task, and the achievement of 'upright' trunk and head during the sitting task was then explored (tables 4B.14 and 4B.15 respectively). All patients who demonstrated a rigid pattern of movement (patient nos. 4, 14 & 15) also failed to achieve either an upright head or trunk posture. The reverse, however, was not true. 'Rigid' pattern of movement is defined in the HAT guidelines and definitions of terms (see Appendix IV).

		Quality of trunk movement			
		Rigid	Free	Not applicable	
Trunk upright	No	3	2	0	5
	Yes	0	6	2	8
		3	8	2	13

Table 4B.14 Cross-tabs HAT tool items "quality of trunk movement" and "trunk upright"

	Quality of trunk movement			
		Rigid	Free	Not applicable	
Head upright	No	3	3	2	8
	Yes	0	5	0	5
		3	8	2	13

Table 4B.15 Cross-tabs HAT tool items "quality of trunk movement" and "head upright"

All three patients who demonstrated a rigid pattern of head and trunk movement during the visual search task also failed to demonstrate a counterbalancing of the head during the forward, and the lateral reach tasks as shown in red in tables 4B.16.and 4B.17 respectively.

Forward reach		Quality of trunk movement			
		Rigid	Free	Not applicable	
Counter balancing with head	No	3	3	1	7
	Yes	0	5	1	6
		3	8	2	13

Table 4B.16 Cross-tabs HAT tool items "quality of trunk movement" and "counterbalancing With head" on forward reach

Lateral reach		Quality of trunk movement			
		Rigid	Free	Not applicable	
Counter balancing with head	No	3	7	1	11
	Yes	0	1	1	2
		3	8	2	13

Table 4B.17 Cross-tabs HAT tool items "quality of trunk movement" and "counterbalancing with head" on lateral reach

When the tool items relating to the presence of trunk movement were explored it was apparent that the two patients (patients 1 & 13) who did not move their trunk during the visual search task were the same two patients who did not demonstrate any trunk movement during the eating task, i.e. they used an 'arm only' feeding action as shown in red in table 4B.18. In addition neither demonstrated selective trunk movement on the upright sitting task.

	Trunk movement			
		No	Yes	
Feeding action	Meet in the middle	0	11	11
	Arm only	2	0	2
		2	11	13

Table 4B.18 Cross-tabs HAT tool items trunk movement for the visual search and eating tasks

As all but one patient (patient no.1) scored maximally on the communication task exploring the relationship between tool items within the task was not appropriate. However this highlighted the fact that the patient who orientated the head 'away' from the researcher did not use 'head gestures' during that episode of communication. In addition this patient failed to score on all other tasks.

Cross tabulation of the results for the two reaching tasks revealed that both the patients (patients 11 & 13) with a counterbalancing reaction on lateral reach (shown in red in table 4B.19) also demonstrated a counterbalancing reaction when reaching forwards.

	Forward Reach			
		No	Yes	
Lateral Reach	No	7	4	11
	Yes	0	2	2
		7	6	13

Table 4B.19 Cross-tabs HAT tool items "counterbalancing with head" on forward and lateral reach

4B.3.3.d Patient perception about head activity and related sensory functions

At the first assessment only two patients (12%) reported having had difficulty moving their heads since their strokes. Patient three reported: *" My head always seems too heavy for my neck"*, and patient seven reported: *"turning to the right is a problem it's uncomfortable I think it's my position in bed that causes it"*.

Two patients reported difficulty in seeing things around them (12%), and five patients reported a change in their vision (31%). Of the patients reporting a change in vision only one had a visual impairment as a result of their stroke documented in their medical notes. Of those without a medically diagnosed or investigated visual impairment patient four reported: " *It (vision) feels a bit more fuzzy than normal*", and patient seven reported: "*There has been a slight decline, I am finding it more difficult to read the paper now*". None of the patients had experienced a change in hearing.

Two patients had suffered from neck pain (12%), one from shoulder pain (6%), and five patients reported having had headaches since their strokes (31%). Five patients reported experiencing episodes of dizziness since their strokes (31%). Patient five reported: "*Initially I felt my head was revolving but that went off after the first day*", and patient six reported: "*Occasionally I feel dizzy with a sick, dizzy headache*"; Patient nine reported: "*I get dizzy all of a sudden when I'm tired, like when I have had visitors for a while*", and patient 13 reported: "*I get dizzy sometimes when leaning forwards from sitting*".

Twelve patients expressed having experienced difficulties with their balance since their strokes (75%). Patient three reported: "*When I sit in the wheelchair I tend to fall forwards and to the left, it's mainly my head that goes and it takes everything else with it*"; patient 15: "*Yes even in sitting I seem to be all over the place but it is getting better slowly*"; patient 8: "*It's my main difficulty. When I sit I lean to the left unless I'm concentrating*"; patient 5: "*My giro wasn't on its bearings it was tilted to the right at first but now it has corrected itself*".

Of the two patients experiencing difficulty moving their heads one reported suffering from neck and shoulder pain since their stroke and the other reported having experienced headaches. Neither had reported episodes of dizziness, but both had experienced difficulties with their balance. The two patients reporting difficulty seeing things around them also reported a change in vision, but neither reported difficulty moving their heads. None of the patients who had suffered from headaches reported neck or shoulder pain. Only one of the patients reporting headache also suffered episodes of dizziness, but four of the five patients experiencing episodes of dizziness also reported balance difficulties.

4B.3.3.d.i Relationship between observed and reported head activity

The sample of fourteen patients with total HAT scores was split into two, according to the response given to the interview questions about difficulty moving their head, episodes of dizziness experienced, and difficulties with balance. The Mann Whitney U test was used to compare the total HAT scores at assessment one of patients describing and those not describing these symptoms. No significant differences were found between the two groups for any of the three symptoms. The results are presented in table 4B.20.

	Difficulty moving head	Episodes of dizziness	Difficulty with balance
Number reporting yes	2	5	11
Number reporting no	12	9	3
Z value	-.227	-1.552	-.867
p value	.791	.147	.456

Table 4B.20 Assessment one relationship between observed and reported head activity

4B.3.3.e Relationship between Head activity (HAT score) and classification of stroke

Using the Man Whitney U test to compare the head activity of those with a LACI classification of stroke and those with either TACI, PACI, POCI, or PICH, no significant difference was found z=-1.568 p=.117. A trend to a higher initial HAT score with a lacunar infarct was however evident. Those with a LACI classification of stroke (n=6) had a median initial HAT score of 7 with a range from 4-10, while those with a classification of PACI, POCI, or PICH (n=8) had a median HAT score of 4.5 with a range from 0-9. When the data was split into those with a TACI or PICH (n=4) and those with LACI, PACI, or POCI (n=10) a significant difference in total HAT scores at assessment one was found z=-2.720 p=.007. Those with PICH or TACI had significantly lower initial HAT scores (median score of 2 with a range from 0-4) than those with LACI, PACI, or POCI (median score of 7 with a range from 4-10). The results of the comparisons between HAT score and classification of stroke are presented in table 4B.21.

	LACI: TACI, PICH PACI, POCI,	TACI, PICH: LACI, PACI, POCI,
Z value	-1.568	-2.720
P value	0.117	**0.007**

Table 4B.21 Assessment one relationship between HAT score and classification of stroke

4B.3.3.f Associations between head activity and function

<u>4B.3.3.f.i Associations between head activity ADL ability, motor impairment, and balance</u>

Associations between head activity (HAT score) and ADL ability motor impairment, and balance were analysed using Spearman Rank Correlation. The Barthel Index was the measure of ADL ability, the Rivermead Motor Assessment the measure of motor impairment, and the Berg balance scale the measure of balance. These functional measures were tested against the measure of head activity, the HAT score, to test whether there was a relationship between head activity and function. A significant correlation was found between HAT score and ADL ability (Barthel Index r=.680 p=.007), all three sections of the Rivermead Motor Assessment; gross function (r=.697 p=.006), leg and trunk (r=.563 p=.036), arm (r=.717 p=.004), and balance (Berg Balance Scale r=.763 p= .002). The significant correlations identified a relationship between head activity and function. The correlations between Head activity (HAT score) and ADL ability, motor impairment, and balance are presented in table 4B.22.

	Barthel	RM GF	RM LT	RM A	BERG
HAT Score					
Rs	**.680**	**.697**	**.563**	**.717**	**.763**
p	.007	.006	.036	.004	.002

Table 4B.22 Assessment one associations between HAT score and function

<u>4B.3.3.f.ii Associations between head activity and seated distance reached</u>

Associations between HAT score and seated forward and lateral reach distances were analysed using Spearman Rank Correlation. Correlations are presented in table 4B.23. A significant correlation was found between distance reached laterally (r=.644 p=.013), identifying a relationship between head activity and seated lateral reach. No significant correlation was found between distance reached on seated forward reach and total HAT score.

	Forward reach	Lateral reach
HAT Score		
Rs	.280	**.644**
p	.333	.013

Table 4B.23 Assessment one associations between head activity and seated distance reached

4B.3.3.f.iii Associations between head activity and sensory impairment and unilateral neglect

Associations between head activity (HAT score) and sensation, and unilateral visual neglect were also analysed using Spearman Rank Correlation. The Nottingham sensory assessment was the measure of sensory impairment, and the BIT the measure of unilateral neglect. Each measure was tested against the measure of head activity, the HAT score, to test if there was a relationship between head activity and sensory impairment or neglect. A significant correlation was found between sensory impairment and HAT score (r=.713 p=.004). No significant correlation was found between unilateral neglect and HAT score, though a trend towards significance is evident. The correlations between head activity (HAT score) and sensation and unilateral visual neglect are presented in table 4B.24.

	NSA	BIT
HAT Score		
Rs	**.713**	.511
p	.004	.062

Table 4B.24 Assessment one association between head activity and sensory impairment and unilateral neglect

4B.3.3.g Associations between distance reached and ADL ability, motor impairment, balance, sensory impairment, and level of unilateral neglect

Associations between distance reached forwards and laterally (measured during the HAT) and ADL ability, motor impairment, balance, sensory impairment, and level of unilateral neglect were analysed using Spearman Rank Correlation. The measures were tested against the measure of distance reached to test whether there was a relationship between distance reached and function, sensation and neglect. The correlations are presented in table 4B.25. No significant correlations were found between forward reach and any of the measures. However, distance reached during the seated forward reach was significantly correlated with distance reached during the seated lateral reach. For the lateral reach significant correlations were found at the 1% level with motor impairment (all sections of the Rivermead Motor Assessment), gross function (r=.740 p=.002), leg and trunk (r=.752 p=.002), arm (r=.696 p=.006), and balance (Berg Balance Scale r=.693 p= .006). A significant correlation was found at the 5% level between and seated lateral reach and ADL ability (Barthel Index r=.626 p=.017), sensory impairment (NSA r=.595 p=.025), and level of neglect (BIT r=.479 p=.030).

		Forward reach	Lateral reach	Barthel	RMGF	RMLT	RMA	Berg	NSA	BIT
Forward reach	Rs		**.697**	.076	.322	.370	.104	.299	.217	.301
	p		**.006**	.797	.262	.192	.723	.299	.457	.295
Lateral reach	Rs	**.697**		**.626**	**.740**	**.752**	**.696**	**.693**	**.595**	**.479**
	p	**.006**		**.017**	**.002**	**.002**	**.006**	**.006**	**.025**	**.030**

Table 4B.25 Associations between distance reached and function, sensation, and unilateral neglect

4B.3.4 Summary of findings – Assessment one

- The head activity of a sample of fourteen patients at the end of week one following first-ever acute stroke has been described in terms of: total HAT score, scores for each of the five tasks and individual tool item ratings.
    - Total HAT scores ranged from the minimum to the maximum possible score for the HAT (0-10).
    - A diverse range of head activity was demonstrated by the sample for all five tasks (as reflected in total HAT scores)
    - A failure to achieve an upright sitting posture was demonstrated by a majority of the patients
    - Differences in the head activity demonstrated to each side was shown by one patient
    - An apparent inability to dissociate head and trunk movements was demonstrated by some patients during the visual search and reaching tasks
    - Two patients showed a reluctance to move their trunks during the visual search task and their heads and trunks during the eating task, and

demonstrated a lack of selective head and trunk movement during the upright sitting task

- Patients reported a very limited insight into any difficulty they had with head activity. Only two patients reported difficulty moving their head. Episodes of dizziness, headaches and difficulties with balance were more frequently reported.

- A relationship was identified between OCSP classification of stroke and HAT score at the end of week one. Those with a TACI or PICH (more severe stroke) had significantly lower initial HAT scores than those with LACI, PACI or POCI.

- HAT score at the end of week one was significantly correlated with ADL ability (Barthel Index score), motor impairment (All three sections of Rivermead Motor Assessment), balance (Berg balance scale and seated lateral reach), and sensory impairment.

- Seated distance reached laterally was significantly correlated with ADL ability, motor impairment, balance, sensory impairment and neglect.

4B.3.5 Change over time: assessments one to three

4B.3.5.a Sample

Nine of the sixteen patients were assessed on all three occasions (see table 4B.1). One of these patients refused to be videotaped. The data from the eight patients with a complete data set at each assessment has been used to analyse change in head activity and function over the six-week assessment period. The median number of days since stroke for the first assessment was eight, with a range from seven to 11. The median number of days since stroke for the second assessment was 24, with a range from 20 to 26. For assessment three the median number of days since stroke was 41 with a range from 36 to 43. The timings for each assessment are presented in table 4B.26.

		Assessment 1 **N=8**	**Assessment 2** **N=8**	**Assessment 3** **N=8**
No. of days since stroke	**Median** **Min-max**	8 7-11	24 20-26	41 36-43

Table 4B.26 Patient assessment timings assessments one to three

4B.3.5.b Patient characteristics

Of the eight patients who were followed from week one to six, six were male and two female. The median age was 76 with a range from 60 to 81. Two patients had a left hemispheric stroke and six a right. Four of the eight patients had a lacunar infarct, one a partial anterior infarct, and the remaining three had a haemorrhagic stroke. The characteristics of the eight patients with a full data set followed over the six-week period are presented in table 4B.27.

Gender	Age	Hemisphere of stroke	OCSP classification of stroke
6 male 2 female	Median 76 Min-max 60-81 IQR 66-77	2 left 6 right	1 PACI 4 LACI 3 PICH

Table 4B.27 Characteristics of patients followed from assessments one to three

4B.3.5.c Change in function from assessment one to assessment three

4B.3.5.c.i ADL ability, motor impairment, and balance

For the eight patients assessed on all three occasions the median Barthel score at assessment one was nine with a range from one to 13. By assessment two the median Barthel had increased to 10.5, and by the third assessment had increased to 17. The median values for all three sub-sections of the Rivermead Motor Assessment increased from assessment one to assessment three. The median score for the Berg Balance Scale was 8.5 at assessment one with a large range from zero to 33. At assessment two the median score had nearly doubled to 16.5, but the range remained large. By assessment three the median score had increased to 29.5, with a range from 22 to 50. The median, spread around the median (IQR), and range values for the three assessments are presented in table 4B.28.

		Assessment 1	**Assessment 2**	**Assessment 3**
Barthel Index				
	Median	9	10.5	17
	Min-max	1-13	7-16	11-19
	IQR	5.5-10	10-14.5	11.5-18
Rivermead Motor Assessment				
Gross function	Median	2	5	6.5
	Min-max	0-5	2-8	5-10
	IQR	1.5-4.5	2.5-5	5-9
Leg and Trunk	Median	3	5	5.5
	Min-max	0-5	3-8	5-10
	IQR	1.5-3	3-6	5-9.5
Arm	Median	4	7.5	9
	Min-max	0-13	1-15	1-14
	IQR	0.5-8	2-11.5	3-12
Berg Balance Scale				
	Median	8.5	16.5	29.5
	Min-max	0-33	5-37	22-50
	IQR	3.5-9	8-28	26-44

Table 4B.28 ADL ability, motor impairment, and balance scores for assessments 1-3

Changes in ADL ability, motor impairment, and balance

Analysis of change in ADL ability, motor impairment, and balance scores from assessment one to three using the Freidman Test revealed a significant change in all scores; Barthel Index p=.001, Rivermead Motor gross function p=.002, Rivermead Motor leg and trunk p= .001, Rivermead Motor arm p=.002, and Berg Balance Scale p=.001. Further analysis of change using Wilcoxon Signed Rank between consecutive assessments (assessments one and two, and two and three) was used to illustrate where the significant change occurred. Barthel Index, Rivermead Motor Assessment gross function, and Berg Balance Scale scores increased significantly between assessments one and two (p=.018) (p=.027) and (p=.017) respectively, and assessments two and three (p=.017) (p=.039) and (p=.018). Change in Rivermead Motor Assessment leg and trunk, and arm sub-section scores both reached a significant level for change between assessments one and two (Wilcoxon p=.017 and p=.017 respectively), but failed to reach a significant level for assessments two to three (Wilcoxon p=.066 and p=.221 respectively). The analysis of change in ADL ability, motor, and balance scores are presented in table 4B.29 with significant values presented in bold.

	Assessments 1-3*	Assessments 1-2 #	Assessments 2 to 3#
Barthel Index	**P=.001**	**P=.018**	**P=.017**
RMA gross function	**P=.002**	**P=.027**	**P=.039**
RMA leg and trunk	**P=.001**	**P=.017**	P=.066
RMA arm	**P=.002**	**P=.017**	P=.221
Berg Balance Scale	**P=.001**	**P=.017**	**P=.018**

Table 4B.29 Changes in ADL ability, motor impairment, and balance scores assessments 1-3

* Freidman

Wilcoxon

4B.3.5.c.ii Distance reached

The distance reached to the side was consistently less than that reached forwards at each assessment point. The median distance reached forwards was 36cm at assessment one, this remained unchanged at assessment two, but increased marginally to 37cm at assessment three. The median distance reached to the side increased from 14cm to 21cm from assessment one to two, but then decreased to 20cm at assessment three. The large range for both forward and lateral reach at assessment one is in part accounted for by the scoring of patient three with a reach of 0cm due to their inability to sit unsupported. The median, minimum and maximum, and spread around the median (IQR) values for distance reached at each assessment are presented in table 4B.30.

		Assessment 1	Assessment 2	Assessment 3
Forward reach	Median Min-max IQR	36 0-43 31.5-38.5	36 24-42 31-41	37 30-48 33-44
Lateral reach	Median Min-max IQR	14 0-30 10.5-21.5	21 13-30 15.5 -27. 5	20 13-30 18.5-26.5

Table 4B.30 Distance reached assessments 1-3

Changes in distance reached

Analysis of change in distance reached between assessments one and three failed to reveal a significant change in distance reached forwards (p= .078 Freidman) or laterally (Freidman p= .078). However, further analysis of distance reached using the Wilcoxon Signed Rank test revealed a significant change in distance reached laterally between assessments one and two (z =-2.313 p=.021), but not between assessments two and three (z=-.595 p=.552). No significant change was found between consecutive assessments for forwards reach.

4B.3.5.c.iii Sensation and unilateral visual neglect

The median score for the Nottingham Sensory Assessment increased steadily from assessment one (42.5) to three (60). The range at all three assessments included the maximum score indicating the absence in any sensory impairment for some of the patients. Two patients scored maximally at the first two assessments, and this had increased to four (half the sample) by the third. A similar picture was evident in Behavioural Inattention Test scores. The median score increased from 138.5 at assessment one to 145.5 at assessment three. Using the cut-off score of 129, only one patient had neglect at assessment one; by assessment two none of the patients had neglect and this remained unchanged at assessment three. The median, minimum and maximum, and spread around the median (IQR) values for NSA and BIT scores at each assessment are presented in table 4B.31.

		Assessment 1	Assessment 2	Assessment 3
Nottingham Sensory Assessment	Median Min-max IQR	42.5 29-64 31.5-61.5	48.5 33-64 40.5-63	60 40-64 44-64
Behavioural Inattention Test	Median Min-max IQR	138.5 116-146 132.5-145.5	144 133-146 137-146	145.5 134-146 142-146

Table 4B.31 Sensation and unilateral visual neglect scores assessment 1-3

Changes in sensation and unilateral visual neglect

Analysis of change in sensory impairment and unilateral neglect from assessments one to three demonstrated a significant change for both NSA Scores (p=.002 Freidman), and BIT scores (p=.006 Freidman). Further analysis of change using Wilcoxon Signed Rank between consecutive assessments revealed a significant change in scores for both measures between assessments one and two (NSA p=.027, BIT p=.028), and two and three (NSA p=.026, BIT p=.026).

4B.3.5.d Changes in head activity from assessment one to three

4B.3.5.d.i Total HAT scores

The total HAT scores at each assessment for each patient are illustrated in table 4B.32. HAT scores ranged from the minimum (zero) to maximum (ten) score over the three assessments. The median HAT scores for assessment one was five with a range from zero to nine. The median scores increased steadily to six by assessment two, and to eight by assessment three. None of the patients scored maximally on the HAT until assessment three, when only one of the sample of eight scored the maximum ten. None of the eight patients saw a reduction in HAT score over the six-week period, but the increase in score (if any) varied considerably from patient to patient.

	Total HAT Score			Change in HAT score assessments one to three
Patient no.	Assessment 1	Assessment 2	Assessment 3	
2	4	4	5	1
3	0	3	6	6
6	8	8	8	0
7	9	9	9	0
12	6	7	9	3
13	6	9	10	4
14	4	5	6	2
15	4	4	8	4
Median	**5**	**6**	**8**	**2.5**
Min-max	**0-9**	**3-9**	**5-10**	**0-6**

Table 4B.32 HAT scores and change in HAT score assessment one to three

Change in HAT scores ranged from zero to six from assessments one to three with a median change in score of 2.5. The change in HAT scores for each patient is presented in table 4B.32. Analysis of change in HAT scores revealed a significant change in HAT score between assessments one and three ($p = 0.014$ Freidman). Further analysis failed to demonstrate a significant change in HAT score between assessments one and two (Wilcoxon $Z = -1.857$ $p = 0.063$). Between assessments one and two, four of the eight HAT scores increased, but four remained unchanged. A significant change was seen between assessments two and three (Wilcoxon $z = -2.226$ $p = 0.026$) where six of the eight scores increased.

4B.3.5.d.ii Changes in individual category ratings for each task

Upright sitting

		Assessment 1	Assessment 2	Assessment 3
Attempt to correct	Yes	6	7	7
	No	1	0	0
Selective movement	Yes	3	4	6
	No	3	3	1
	Not applicable	1	0	0
Trunk upright	Yes	4	4	6
	No	3	3	1
Head upright	Yes	2	3	5
	No	5	4	2
Head position	Flexion	0	0	0
	Extension/protraction	1	0	0
	Right side flexion	1	0	0
	Left side flexion	0	1	0
	Right rotation	1	1	0
	Left rotation	2	2	2
	Not applicable	2	4	5
Maintained	Yes	2	4	5
	No	0	0	0
	Not applicable	6	4	3

Table 4B.33 Tool item ratings for the upright sitting task assessments 1-3

Over the six weeks (three assessments), there was a gradual increase in the number of patients attempting to correct their posture when requested to do so, doing so with selective movement, and achieving an upright head and trunk. At assessment one, four of the seven patients achieved an 'upright trunk' position, and only two an 'upright head'. This increased to four and three respectively at assessment two. By assessment three all but one patient had achieved an 'upright trunk' and all but two an 'upright head'. Patients without an 'upright head' were rated as having a number of different head positions. Ratings for each of the tool items for the upright sitting task across the three assessments are presented in table 4B.33.

Visual search

		Assessment 1	Assessment 2	Assessment 3
Search strategy	Both ways	7	7	7
	One way	0	0	0
Trunk movement	Yes	6	7	7
	No	1	0	0
Quality of head and trunk movement	Move freely	4	7	7
	Rigid	2	0	0
	Not applicable	1	0	0

Table 4B.34 Tool item ratings for the visual search task assessments 1-3

All patients searched to both sides on all three assessments. At assessment one, one patient did not use trunk movement and two moved their heads and trunks in a rigid manner. By assessment two all patients moved their trunks and did so freely. This was maintained at assessment three. Ratings for each of the tool items for the visual search task across the three assessments are presented in table 4B.34.

Communication

		Assessment 1	Assessment 2	Assessment 3
Orientation of head right	Away	0	0	0
	Towards	1	1	2
	Towards and away	6	6	5
Orientation of head left	Away	0	0	0
	Towards	3	3	2
	Towards and away	4	4	5
Uses head for gesture right	Yes	7	7	7
	No	0	0	0
Uses head for gesture left	Yes	7	7	7
	No	0	0	0
Size of head gesture right	Frequent and Large	1	3	1
	Moderate	5	4	6
	Minimal and small	1	0	0
Size of head gesture left	Frequent and Large	0	2	0
	Moderate	6	4	7
	Minimal and small	1	1	0

Table 4B.35 Tool item ratings for the communication task assessments 1-3

All patients orientated their heads towards or towards *and* away (with a predominance of towards *and* away) to both the right and the left at all three assessments. All patients used their heads to gesture to both the right and left at all three assessments. Gesture size varied at assessment one and two from frequent and large to minimal and small. By assessment three all gesture sizes were moderate or frequent and large. Ratings for each of the tool items for the communication task across the three assessments are presented in table 4B.35.

Eating

		Assessment 1	Assessment 2	Assessment 3
Feeding action	Meet in the middle	6	6	7
	Arm only	1	1	0
	Head to pot	0	0	0

Table 4B.36 Tool item ratings for the eating task assessments 1-3

All but one patient used 'meet in the middle' feeding action at the first two assessments. By the third assessment all patients used the 'meet in the middle' action. Ratings for each of the tool items for the eating task across the three assessments are presented in table 4B.36.

Reaching

		Assessment 1	Assessment 2	Assessment 3
Counterbalance with head on forward reach	Yes	2	3	3
	No	5	4	4
Counterbalance with head on lateral reach	Yes	1	2	2
	No	6	5	5

Table 4B.37 Tool item ratings for the reaching task assessments 1-3

Two patients used their heads to counterbalance on the forward reach, and one on the lateral reach at assessment one; this rose to three and two respectively by assessment two. There was no change between assessment two and three. Ratings for each of the tool items for the reaching task across the three assessments are presented in table 4B.37.

4B.3.5.e Changes in patient perception of head activity and related sensations

In this section the responses of the eight patients to the interview questions about head activity, vision, hearing, neck and shoulder pain, headaches, dizziness and difficulties with balance, over the three assessments, are presented.

At assessment one, two patients reported difficulty moving their heads (as described for assessment one in Section 4B.3.3), and one patient reported a change in vision, but no patients described any difficulty seeing things around them. Two patients reported neck pain since their strokes and one described shoulder pain. Four patients described having had headaches since their strokes, two reported episodes of dizziness and six described difficulties with balance. One of the patients not reporting any difficulty with balance responded: *"Within what I am able to do balance has not been a problem"*. This patient went on to describe difficulty with balance at both assessment two and three.

At assessment two, none of the patients reported any further change in vision, and none reported difficulty moving their heads or seeing things around them. One patient reported neck and shoulder pain; this patient had not reported neck or shoulder pain at assessment one. Three patients reported having suffered from headaches since the first assessment; this included the patient with neck and shoulder pain and the only patient to describe episodes of dizziness. All the patients reporting headaches and dizziness also reported these symptoms at assessment one. Six patients reported difficulty with balance at assessment two, five of whom had done so at assessment one.

By assessment three, none of the patients reported any further change in vision, any difficulty seeing things around them, any difficulty moving their heads, or any neck or shoulder pain. In response to the question *" Since I last saw you have you had any difficulty seeing things around you?"* patient 13 reported: *"No, in fact I am taking more interest in my environment now"*. Four patients reported experiencing headaches in the three weeks since assessment two, three of whom had experienced headaches throughout the six-week period, the other describing them for the first time. One patient reported episodes of dizziness; this patient had reported these symptoms from assessment one. This patient had also described suffering from headaches throughout the assessment period. At assessment three, four patients reported difficulty with balance, all of which had done so at assessment two. One patient reported: *"As I do more, it (balance) is more apparent as a problem"*.

4B.3.5.f Relationship between initial HAT score and functional outcome at six weeks

The sample of patients with a complete data set at all three assessments was divided into two groups by initial HAT score; those with a HAT score of less than 5 (median HAT score) n=4, and those with five or more n=4. The Mann Whitney U Test was then used to compare the ADL ability, motor impairment, balance, sensory impairment and level of unilateral neglect at six weeks of those with a low initial HAT score with those with high initial HAT score. No significant difference was found between the two groups for any of the above outcome measures. The Z and p values are presented in table 4B.38.

Assessment	Z value	P value
Barthel ADL Index	-.735	.462
RMA gross function	-.619	.686
RMA leg and trunk	-.619	.686
RMA arm	-1.191	.343
Berg Balance Scale	-.581	.686
NSA	-1.076	.343
BIT	-1.548	.200

Table 4B.38 Relationship between initial HAT score and functional outcome at six weeks

On closer inspection of the two groups it was apparent that the group with initial low HAT scores was younger (median age 68.5 (min-max 60-77)) to a level approaching significance p=.076. The median age of the initial high scoring group was 77 (min-max 76-81). In addition the low scoring group also had more severe stroke with three patients having PICH and one patient with a LACI. In comparison the high scoring group comprised of one PACI and three LACI. Further comparisons between the two groups are presented in table 4B.39.

		Assessment at end of six weeks						
		Barthel Index	RMA gross function	RMA leg & trunk	RMA arm	Berg Balance	NSA	BIT
Low initial HAT score n=4	Median Min-max	17.5 11-15	7 5-10	7.5 5-10	5 1-12	36 26-50	52 40-64	143 134-146
High initial HAT score n=4	Median Min-max	14.5 11-18	6.5 5-8	5.5 5-8	10 9-14	29.5 22-37	64 42-64	146 145-146

Table 4B.39 Comparison between patients with low and high initial HAT scores at six weeks

Comparing the median values of the scores for the Barthel Index, all three sections of the Rivermead Motor Assessment and the Berg Balance Scale revealed that those with low HAT scores at assessment one had higher median scores for all of the above assessments at week six. In contrast, those with low HAT scores at assessment one had lower median scores for the Nottingham Sensory Assessment and the Behavioural Inattention test at week six.

Again, with the sample divided into two groups by initial HAT score, the Mann Whitney U Test was used to compare the HAT scores at six weeks of those with initial low, and those with initial high HAT scores. A significant difference was found between the two groups with those initial high HAT scores continuing to score higher on the HAT at assessment three (z=-2.205 p=.029).

4B.3.6 Summary of findings – Assessments one to three

- The changes in head activity over the first six weeks following stroke have been described for a sample of eight patients. Changes in head activity have been described in terms of total HAT scores, scores for each of the five tasks, and individual tool item ratings.

- A significant change in HAT scores from assessments one to three (Friedman p=. 0014) was found. Change in HAT scores ranged from zero to six with a median change in score of 2.5.

- Only two patients reported difficulty moving their heads at assessment one, and by assessments two and three none of the patients reported any such difficulty. However, reports of headaches, episodes of dizziness and problems with balance persisted at the third assessment.

- No significant difference was found in terms of ADL ability, motor impairment, or balance control at assessment three (end of week six), between patients with a low HAT score, and those with a high HAT score at assessment one (end of week one).

4B.4 Individual patient profiles

Looking at the head activity of the sample of patients as a whole revealed a far from simple relationship between head activity and function. This is likely, in part, to be due to the very small sample size. However, in an attempt to further explore the relationship between head activity and function found for this sample, individual patient profiles for six of the sixteen patients recruited to the study are presented and discussed. These patients represent the extremes of the sample, provide detailed examples of patients lost to study follow-up, and illustrate patients whose change over the six weeks was expected, and those whose progress was more unforeseen.

The first two patients presented are examples from each of the extremes of HAT scores; one patient scoring the minimum score of zero, one scoring the maximum ten. Both patients were lost to study follow-up.

Patient number 1: Lowest total HAT score at assessment one.

	Total HAT	Barthel	RMA gross function	RMA Leg & trunk	RMA Arm	Berg Balance	NSA	BIT
Assessment 1 Score	0	4	1	3	2	4	26	103

Table 4B.40 HAT, ADL ability, motor, balance, sensory, and neglect scores for patient no. 1

Patient number one had a right hemispheric infarct, was the only patient with a total anterior circulation infarct recruited to the study, and one of only two patients with neglect. Scores for head activity, ADL ability, motor impairment, balance, sensory impairment, and neglect are presented in table 4B.40. The patient was able to complete the HAT but scored the lowest possible score of zero. There was severe disability following the stroke with a Barthel of four and Rivermead Motor Assessment gross function of only one. Sensation of pressure and light-touch and kinaesthetic sensation were impaired for both the left upper and lower limbs with a score of only 26 out of a possible 64 on the Nottingham Sensory Assessment. The patient presented with severe neglect, scoring 103 on the BIT, well below the cut-off score of 129, and failing four out of the six tests.

Unfortunately this patient became medically unstable and was transferred to an acute medical ward and was lost to the study follow up at end of weeks three and six. For this reason the patient was included in the analysis at the end of assessment one but was excluded from analysis of change in head activity and function over the first six weeks of recovery.

The opportunity to see the effect of severe and possibly enduring neglect on head activity over six weeks was not realised. The missing data meant that the results from this patient with initial low HAT and function scores were not analysed when looking at change in head activity over the first six weeks following stroke. This emphasises the loss of an extreme case to the change group, a group that was already a sub-sample of a very limited initial sample.

Patient number 11: Highest total HAT score at assessment 1 scoring the maximum possible score of ten.

	Total HAT	Barthel	RMA gross function	RMA Leg & trunk	RMA Arm	Berg balance	NSA	BIT
Assessment 1 Score	10	14	5	6	12	33	64	144

Table 4B.41 HAT, ADL ability, motor, balance, sensory, and neglect scores for patient no. 11

Patient number 11 had a left hemispheric lacunar infarct. Scores for head activity, ADL ability, motor impairment, balance, sensory impairment, and neglect are presented in table 4B.41. This patient had a moderate level of disability one week following her stroke; she scored the maximum score of ten on the HAT, was able to stand and take ten steps unaided, but was unable to walk 10m without assistance. Patient 11 had no sensory impairment or neglect on testing. Patient 11 was discharged home independently mobile before the end of week three. Again, this patient was included in the analysis at the end of assessment one but was excluded from analysis of change in head activity and function over the first six weeks of recovery.

Losing this patient to follow-up meant that data from a patient scoring maximally on the HAT and relatively high on functional measures were not analysed with the change data. Again this is an example of the loss off an extreme case in the change group. It was expected that this patient would continue to improve functionally with both further motor recovery and increasing confidence on discharge home.

The following two examples are of patients whose HAT scores appear to be in variance with scores for the measures of ADL ability, motor and sensory impairment, and balance.

Patient number 2: Low HAT score throughout the six weeks but measures of motor function and balance increased markedly.

	Total HAT	Barthel	RMA gross function	RMA Leg & trunk	RMA arm	Berg balance	NSA	BIT
Assessment 1 Score	4	9	2	4	0	9	32	143
Assessment 2 Score	4	10	3	6	1	8	40	146
Assessment 3 Score	5	18	9	10	1	46	64	146

Table 4B.42 HAT, ADL ability, motor, balance, sensory, and neglect scores for patient no. 2

Patient number two had a left hemispheric lacunar infarct. Patient number two had an initial HAT score of 4 (low). The HAT score remained unchanged at assessment two and only increased by one point at assessment three. The increase in HAT score was accounted for by achieving 'attempt to correct using selective movement' on the 'Upright Sitting' task at assessment three. All other HAT scores remained unchanged. In contrast large changes in ADL ability, motor function, balance and sensory function were seen between assessments one and three. Scores for head activity, ADL ability, motor impairment, balance, sensory impairment, and neglect are presented in table 4B.42. The patient scored 18 out of a possible 20 on the Barthel Index and their Berg Balance score of 46 at assessment three was above the cut-off of 45 recommended by Berg et al. (1992) for safe independent ambulation. This is despite a HAT score of only five with the patient rated as not achieving an 'upright' trunk or head position on the 'upright sitting' task, and as not demonstrating a righting reaction with the head on either reach. In addition the patient had only minimal upper-limb motor function with a score of only one on the arm section of the RMA at six weeks. Patient number 2 consistently reported no difficulty with head activity, no episodes of dizziness, no change in vision, and no problem with balance. Patient number 2 is an example of a relatively high functional achiever at six weeks who scored consistently low on the HAT throughout the six weeks.

Perhaps most interesting is the patient's high balance score when compared to the low HAT score, including the rating of not achieving an upright head or trunk in sitting. In this case, recovery of head activity appears to lag behind that of recovery of function and balance. What movement strategies the patient is using for this lack of recovery of head activity during functional activities, other than those rated by the HAT (e.g. when walking), cannot be answered. The results also highlight the relatively short time frame over which the patient was followed. It is not possible to say whether the HAT score improved after assessment three, or whether functional ability continued to improve, reached a plateau, or declined. This patient's results draws attention to the finding that it may be possible to function relatively independently with poor head activity. However, the longer-term impact of poor head activity on functional ability has not been tested. It remains feasible that patient 13's rehabilitation potential may not be met without further recovery of head activity.

Patient 13: Maximum HAT score at the end of week six but relatively low scores of ADL ability, motor and sensory function, and balance.

	Total HAT	Barthel	RMA gross function	RMA leg & trunk	RMA Arm	Berg balance	NSA	BIT
Assessment 1 Score	6	10	5	4	5	8	29	146
Assessment 2 Score	9	10	5	6	5	17	41	145
Assessment 3 Score	10	12	5	6	9	28	42	146

Table 4B.43 HAT, ADL ability, motor, balance, sensory and neglect scores for patient no. 13

Patient 13 had a right hemispheric lacunar infarct. Patient 13 scored six on the HAT at the end of week one. All dropped HAT scores were from the 'eating' and 'upright sitting' tasks, the patient consistently demonstrated a head righting reaction on both forward and lateral reach. Achieving upright head position using selective movement and maintaining the upright position account for the increase in HAT score between assessments 1 and 2. Using the coordinated feeding action of 'meet in the middle' at assessment three rather than 'arm only' action accounts for the increase in score to the maximum ten between assessments two and three. Despite the final HAT score of ten, patient 13 had relatively low scores on Rivermead Motor Assessment gross function (5), leg and trunk (6) and the Berg Balance Scale (28) at assessment three. The patient was unable to take ten steps independently and had an enduring sensory impairment. Scores for head activity, ADL ability, motor impairment, balance, sensory impairment, and neglect are presented in table 4B.43. Patient 13 is an example of a patient with relatively low function at six weeks but with a high (maximum) HAT score.

The question arises as to whether this patient, though slow to regain independence with only small improvements in motor function and ADL ability, has a good long-term prognosis. Could a maximum score of ten on the HAT, perhaps most noteworthy being the consistent presence of head righting on reaching, be an indicator of good functional outcome in the longer term given more time and rehabilitation for further improvement of motor function and balance control? A study comprising a larger sample and with a longer time frame of follow-up is required to answer this question.

The following two examples are of patients with HAT scores and functional scores that increased over the six-week assessment period as expected.

Patient 15: Low HAT score increasing to high HAT score over the six weeks with corresponding rise in ADL ability, motor, balance, and sensory scores.

	Total HAT	Barthel	RMA gross function	RMA leg & trunk	RMA Arm	Berg balance	NSA	BIT
Assessment 1 Score	4	5	1	1	1	3	31	140
Assessment 2 Score	4	13	5	8	9	16	33	144
Assessment 3 Score	8	19	10	10	12	50	40	146

Table 4B.44 HAT, ADL ability, motor, balance, sensory and neglect scores for patient no. 15

Patient number 15 had a small right hemispheric intracerebral haemorrhage. Between assessments one and two there was no change in the HAT score of four, but an increase in ADL ability, motor, and balance impairment was seen. The Barthel Index score increased from five to thirteen, Rivermead Motor Assessment gross function from one to five, leg and trunk from one to eight, and arm from one to nine. Sensory impairment increased by only two points from 31 to 33. Between assessments two and three there was a marked increase in both HAT score (to eight), and Berg Balance Scale score (from 16 to 50). In addition, all Rivermead Motor Assessment sections and Nottingham Sensory Assessment scores increased. The increase in HAT score was accounted for by achieving an 'upright head' and 'upright trunk' posture and using 'selective movement' during the 'upright sitting' task. Scores for head activity, ADL ability, motor impairment, balance, sensory impairment, and neglect are presented in table 4B.44.

It is interesting to note (again) the relatively high Berg Balance Scale Score, despite the patient failing to demonstrate head righting during either of the seated reaches. What if any impact this will have on longer-term functional outcome remains unknown. Despite the lack of initial recovery of head activity for this patient the HAT score increased in the second three-week period following stroke. Such results highlight the type of patient that may benefit most from a targeted specific head and trunk intervention, with the aim of improving head activity and balance control earlier in the recovery phase following acute stroke.

Patient number 3: Lowest HAT score at assessment one increasing throughout the six weeks with corresponding rise in ADL ability, motor, balance, sensory, and neglect scores.

	Total HAT	Barthel	RMA gross function	RMA leg & trunk	RMA Arm	Berg balance	NSA	BIT
Assessment 1 Score	0	1	0	0	0	0	35	116
Assessment 2 Score	3	7	2	3	1	5	45	133
Assessment 3 Score	6	11	5	5	1	26	49	134

Table 4B.45 HAT, ADL ability, motor, balance, sensory, and neglect scores for patient no. 3

Patient number 3 had a right frontal lobe primary haemorrhage. Patient number three was the most severely disabled of the sample at assessment one with a Barthel score of only one illustrating the patient's full dependency. The patient scored zero on all sections of the RMA, scored 35 on the Nottingham Sensory Assessment with sensation to pressure and light-touch and kinaesthetic sensation being impaired for both the left upper and lower limbs. Patient no. 3 scored 116 on the Behavioural Inattention Test, indicating the presence of neglect. This patient was given a score of zero for the HAT, being unable to sit independently at assessment one. A steady rise in scores on all measures occurred between assessment one and two with the achievement of independent sitting balance and the recovery of neglect. The HAT score had increased to three during this time with the patient scoring one for 'searching both ways' on the 'visual search task', and two on the 'communication task' for 'orientating their head towards' the researcher and 'using the head for gestures' to both the right and left. By assessment three the HAT score had increased to six, with the patient achieving an 'upright trunk' during the 'upright sitting task', using the 'meet in the middle' feeding strategy during the 'eating task' and demonstrating a 'counterbalancing with the head' on the forward reach. The Berg Balance Scale Score had increased to 26, Rivermead Motor Assessment gross function and leg and trunk had increased to five though there was no improvement in upper limb with the Rivermead Motor Assessment arm score remaining at one. Scores for head activity, ADL ability, motor impairment, balance, sensory impairment, and neglect are presented in table 4B.44.

It is not known whether the change in HAT score seen between assessment one and two reflects a real change in head activity, or just the ability to sit independently allowing individual tasks on the HAT to be rated. However, the recovery of neglect, and scoring only on the visual search and communication tasks of the HAT at assessment two, suggest that the former is the more likely. It is interesting to note the order in which patient number 3 scored for the HAT tool items, being the only patient with an initial score of zero to be followed over the six-week period. At assessment two the patient scored only for the tool items assessing social interaction with the environment, and failed to score on items rating the ability to achieve an upright head and trunk in sitting, dissociate head and trunk movement, and coordinate head and trunk movement with upper-limb activity. These results suggest that not only do the visual search and communication tasks tap a different feature of head activity, but that patients who present with neglect may show a unique and possibly delayed pattern of recovery of head activity.

Again, this patient profile highlights the type of patient that may benefit most from specific head and trunk intervention with the goal of reducing the time since stroke to achieve good head activity, balance control, and functional independence to their maximum rehabilitation potential.

Section 4C

Discussion of the head activity used by healthy adults and patients with acute stroke

4C.1 Discussion of the characteristics of head activity used by healthy adults and patients following acute stroke

Two small studies were undertaken in which the HAT was used for the very first time with a sample of healthy adults, and a sample of patients following acute stroke; the population for whom the HAT was developed.

The study aims were:

i. To describe the head activity used by a small sample of older healthy adults.
ii. To describe the head activity used by patients with first-ever acute stroke.
iii. To gain an understanding into the patient's perspective of any difficulty with head activity experienced following stroke.
iv. To identify any relationships between head activity and classification of stroke, ADL ability, level of motor and sensory impairment, balance, and the presence of neglect.
v. To profile the changes in head activity during the first six weeks following acute stroke.

Each of the study aims is discussed in turn below, after which the limitations of the study are considered.

4C.1.1 Aim 1: To describe the head activity used by a small sample of healthy adults

4C.1.1.a Subject characteristics

Participants over the age of forty were recruited to the study to reflect the age of the majority of people with stroke. It was not possible to recruit an aged-matched sample, as the continuing development and first use of the HAT necessitated its use on a sample of healthy adults before being used with patients with acute stroke. The younger than anticipated sample (median age 49) was in part due to a failure to recruit the very elderly, a likely result of the difficulties associated with hospital visiting, and the presence of multiple pathologies associated with people of this age.

4C.1.1.b Head activity

4C.1.1.b.i Cervical spine range of motion

Range of cervical spine motion was measured to rule out the possibility of a physical restriction in range impacting on head activity as rated by the HAT. All healthy adult participants had within "normal" active range for all directions of movement, and none of the participants had to be excluded from the study. Unfortunately no study could be found reporting cervical range of movement measured using the CROM for a comparable age group of healthy adults.

4C.1.1.b.ii HAT score

Although not designed specifically to rate the head activity of healthy adults (the distinct clustering of the ratings reflect this), the HAT has been used successfully to describe the head activity of a small sample of healthy adults over 40 years of age. As all participants had "normal" range of cervical motion and did not report any recent history of neck pain, it seems unlikely that head activity, as rated by the HAT, was compromised by restricted range of cervical motion or pain. Total HAT scores ranged from eight to ten with a median score of ten (the HAT maximum). The consistent high scoring and 'ceiling effect' reflect the design of the HAT specifically for patients with acute stroke. The individual tool item ratings are discussed below for each task in turn.

Upright sitting task

The upright sitting results revealed a distinct pattern of healthy adult head activity. All participants were rated as 'attempting to correct' their posture, and doing so with 'selective movement'. All achieved an 'upright head' and 'upright trunk' position, and were able to 'maintain' the upright position. These results corroborate the informally reported observations of what constitutes 'normal movement' as described by the physiotherapy pioneers (e.g. Brunnstrom, 1970; Knott and Voss, 1968; Carr and Shepherd, 1987; Bobath, 1990 (see Sections 1.1.5.a and 1.2.3.c)).

Visual search

The results for the tool item 'search strategy' were unsurprising for a sample of healthy adults, with all subjects looking to both sides to count the targets. The results for the tool item 'trunk movement', however, were less clear-cut, with half the participants using their trunks to search and the half their heads alone. Why half the subjects used their trunks during the visual search and half did not remains unanswered. On further analysis of the video recordings, however, a possible association with use of trunk and speed of movement was apparent. Subjects appearing to search more quickly tended to use head rotation alone, whereas subjects appearing to move more slowly used a combination of head and trunk movement. The relationship between speed of movement and the coordination of head and trunk movement was not rated using the HAT. Further exploration of any such relationship would require three-dimensional computerised motion analysis and was not within the scope of this study.

Communication

All the healthy adult subjects orientated themselves towards the researcher for a majority if not all of the conversation to each side, and were rated using the "towards" and "towards and away" categories for the tool item 'orientation of the head'. This is in keeping with the theory that engaging as a recipient of somebody's narrative requires turning to gaze at the speaker (Goodwin, 1986). Changes in the orientation of the head during the conversation as shown by a majority of the participants may have been in an attempt to further maintain engagement by shifting posture (Kendon, 1990; Schegloff, 1997; and Robinson, 1998). All participants used their heads for gesture, and gesture use is known to enhance engagement in conversation (Goodwin, 1986; Heath, 1986). The range in size and frequency of gestures used suggests that gesture size and frequency may depend on several factors including the topic of conversation, the participant's personality and/or the level of anxiety about the test, and the presence of a video camera. There was however, a clear trend towards the use of "frequent and large" and "moderate" head movements for gesture during this task, with only one participant demonstrating "minimal and small". Differences in gross head activity due to laterality were not envisaged during the communication task with healthy adult participants. There was a tendency for subjects to use similar head activity strategies during the communication task (gesture size, frequency and head orientation), to both the left and the right. Where variation did occur, differences were between adjacent categories.

Eating

Despite the variation in feeding action expected within a sample of healthy adults all subjects were rated as using the "meet in the middle" strategy (a coordinated movement of head, trunk and upper limb). The rating of all participants as using the same feeding action demonstrates the gross nature of categorisation of head activity required by the HAT.

Reaching

A majority (18 out of the 20) of subjects demonstrated head counterbalancing during both the forward and lateral reach. This is in keeping with 'normal movement strategies' described by physiotherapists specialising in movement analysis (e.g. Bobath, 1990; Edwards, 1996). Bobath (1990) describes righting reactions occurring in conjunction with a voluntary movement, and of being activated when balance is perceived to be compromised. Such reactions serve to maintain body alignment appropriate to a position (Edwards, 1996).

In this study only two subjects did not demonstrate a head righting reaction for either reach direction, making any exploration of a relationship between distance reached and the presence of a head righting reaction unfeasible. The suggestion that distance reached alone is not an adequate measure of dynamic balance, but that recording the strategy used during the reach could provide valuable information about postural control has been proposed for reaching in standing (Horak, 1987; Wernick-Robinson et al., 1999; Shumway-Cook, 1996). Horak (1987) and Shumway-Cook (1996) also suggested that identifying the reaching strategy used, and therefore giving consideration to movement efficiency, might assist in the assessment and treatment planning of people with balance impairments.

4C.1.1.b.iii Seated distance reached

No other study could be found comparing forwards and lateral reaches in sitting. In the results presented here a relatively large difference in the distance reached in the two directions was found, with greater distances reached forwards (median 46cm) than to the side (median 35cm). The results found in this study support the thinking of Campbell (1998) that the seated lateral reach is potentially more destabilising than the forward reach, as subjects reach the perimeter of their base of support earlier when reaching to the side. Despite the distinct differences between the demands of the forward and lateral reaches, there was a significant positive correlation between distance reached in each direction. This was not surprising, as both reaches require movement of the body's centre of mass towards the perimeter of the base of support, challenging dynamic sitting balance. The results suggest that the lateral reach in sitting may be more sensitive to a reduced level of dynamic balance, with the perceived limit of stability being reached sooner than when reaching forwards.

4C.1.2 Aim 2: To describe the head activity used by patients with first-ever acute stroke

4C.1.2.a Patient characteristics

The sample was moderately to severely disabled at week one following stroke as would have been expected from an in-patient sample. The severity of stroke and the age of the sample were similar to those used in other studies assessing patients within the first two weeks following stroke (e.g. Wade et al., 1985; Taylor et al., 1994). Those not admitted for in-patient rehabilitation were excluded from the study, as were the medically unstable and those with severe communication problems. Thus the sample did not include those at either end of the spectrum of stroke severity. The limitations of the sample are discussed in more detail in Section 4B.5.5.a.

4C.1.2.b Head activity

4C.1.2.b.i Range of movement

The CROM was used to measure the range of cervical spine movement. It is acknowledged that the CROM has not, to date, been validated for use with patients with acute stroke but it was deemed by the researcher to be better than "eyeballing" range of movement as is common in clinical practice. An accurate method of measuring whether patients had within normal range of movement was necessary to remove the possibility that a biomechanical restriction in range could have impacted on head activity. The results of the HAT could therefore be interpreted solely in terms of movement pattern. Although severe cervical dysfunction was an exclusion criterion, it was not used to exclude anyone in this study. This may have been because of the small sample size and in a larger study it might have come into effect.

It is also recognized that those excluded for other factors may also have had cervical spine dysfunction. It was perhaps surprising that only one patient had restricted range of movement, and only in a single direction. However, "normal" range, as used in this study, was aged matched for the study sample. The effect of this patient's limited range of cervical extension on the HAT results is not known. It is likely that with half the available range of extension and normal range in all other directions any effect would have been minimal and would not have affected the gross rating required for the HAT. It was interesting to note that none of the patients had deterioration in range of movement to less than the study-defined "normal" in the first six weeks following stroke. No study has been found that reports the range of cervical spine range of movement in patients with acute stroke. One study by Tsur and Solzi (1996) reported the range of movement in patients with chronic stroke, but unfortunately only rotation and side-flexion are reported, and range of movement was only compared between movement towards the hemiplegic side and the unaffected side. For these reasons any comparison with the results obtained in this study would be meaningless.

4C.1.2.b.ii HAT score at assessment one

Total HAT scores at assessment one ranged from the minimum to the maximum score, providing evidence that some patients' head activity was relatively unchanged by their strokes (e.g. patient number 11), while some were severely affected (e.g. patient number 1). Scores for each of the five tasks also ranged from minimum to maximum. The small numbers involved in rating individual categories for tool items resulted in some categories remaining unused, and caution is required when looking at relationships between the tasks. However, the results from this study provide an early indication that a relationship between ratings for tool items on different tasks may exist. The individual tool item ratings are discussed for each task in turn below.

Upright sitting task

In rating the upright sitting task all categories except one were used. The un-rated category was for the tool item 'maintained'. All patients were rated as maintaining their upright posture (using the "Yes" category) leaving the "no" category un-rated. 'Maintained' was only rated if patients achieved an upright head and trunk. It was however, noted from the video recordings, that some patients not achieving an upright position were seen to gradually sink from their position. With the small numbers in this study it is not possible to say whether not maintaining a position is a feature demonstrated only by those who are unable to achieve an upright position, or whether, with greater numbers, some patients who did achieve an upright position would have been unable to maintain it. Just over half of the patients at assessment one used selective movement when attempting to sit more upright, and again just over half achieved an upright trunk position but only 38% achieved an upright head at assessment one. The proportion of patients achieving an upright trunk at assessment one is similar to the proportion rated as having a 'midline trunk posture' in the study by Taylor et al. (1994).

Visual search

All but one category was rated for the visual search task. The category not rated was "Incomplete search" for the tool item 'search strategy'. Only one patient failed to search both ways. Eleven patients used their trunks to search whilst two moved only their heads. It is not possible to decipher from the results whether moving the trunk during the visual search tasks is a positive or negative feature of head activity. Looking at the results from the healthy adult study, and the patient study, a mixed picture is evident. In this study the two patients who did not use their trunks were the same two that did not use their trunks during the eating task, and did not use selective movement during the upright sitting task, indicating that perhaps not using the trunk reflected an inability to dissociate the head and trunk to produce a coordinated movement pattern. However, in the healthy adult study half the sample did not use their trunk and it was noted by the researcher that those not using their trunk searched more quickly. Rating whether or not the trunk was used did allow the rating of the quality of trunk movement. The three patients demonstrating a rigid movement pattern also failed to achieve an upright trunk or head in the upright sitting task or a counterbalancing of the head during the lateral reach task. This suggests the rigid movement pattern is associated with other low scoring features of head activity demonstrated during different tasks, and supports the clinical thinking that fixing the head on the trunk during a dynamic task is deployed when balance is impaired. The visual search task also picked up the patient with neglect being the only patient rated as not searching both ways. This movement pattern is expected with a patient with unilateral neglect, as a clinically related feature of neglect is a failure to search for stimuli presented in the hemispace contra-lateral to the brain injury (Freidland and Weinstein 1977; Heilman and Valenstein 1979).

Communication task

All categories were rated for the communication task. The communication task also identified the patient with neglect. The patient with neglect was the only patient to orientate the head away from the researcher and not to use gestures when communicating with the researcher to their hemiplegic side. This again is in line with a clinically related feature of neglect, that of failing to orientate to stimuli presented in the hemispace contra-lateral to the brain injury (Freidland and Weinstein 1977; Heilman and Valenstein 1979). A study with greater numbers and increased diversity of the sample would provide the information as to whether this task would only identify those with neglect or whether other patients, perhaps with severe stoke but without neglect, would also show, for example, lack of gesture use.

Eating task

Two out of the three categories were used to rate the tool item 'feeding action'. All but two patients demonstrated the 'meet in the middle' feeding action during eating. The remaining two patients demonstrated the 'arm only' action meaning they did not move their trunks while bringing the spoon to their mouths. None of the patients demonstrated the 'head to pot' feeding action where trunk and head flexion are the dominant feature. The finding that the patients using the 'arm only' feeding action were the same two patients who did not demonstrate any trunk movement during the visual search task, or use selective trunk movement on the upright sitting task suggest that a relationship between similar movement patterns used during different tasks may exist (see Section 4B.5.1.b.ii Visual search). Again, this needs to be explored further in a study with a larger sample size.

Reaching task

Half the patients demonstrated a counterbalancing of the head on the reaching task at assessment one. In contrast, only two of the fourteen patients demonstrated a counterbalancing of the head on the lateral reach. The high prevalence of a failure to demonstrate a balance reaction during the seated reaching tasks in this study is in line with the high proportion of patients who are known to have impaired postural control following stroke. The results also support the suggestion by Campbell (1998) that a seated lateral reach is more challenging than a seated forward reach. In looking at the relationship between the two reaching tasks it was apparent that both patients with a counterbalancing of the head on the lateral reach also demonstrated a counterbalancing of the head on the forward reach. Whether there was a hierarchical relationship between the two categories could only be explored by looking at the data over all three assessments (see Section 4B.5.4.a.iii).

4C.1.2.c Distance reached in sitting

From both watching patients undertake the reaching tasks, and from analysing the HAT results, it is suggested that lateral reach in sitting gives more clinically relevant information both in terms of distance reached and in HAT rating than the forward reach. In terms of distance reached there was a significant association between distance reached to the side and ADL ability, motor impairment, and balance; no such relationship was found for distance reached forwards. From watching the video recordings it was evident that the lateral reach requires the subject to move out of his or her base of support earlier than the forward reach. Campbell (1998) supports this observation. However, there are limitations associated with measuring a seated reach, not least of which is that to some extent it is a measure of willingness to move rather than ability to move. In the analysis of distance reached consideration must therefore be given to the possibility that subjects may adopt a more conservative "safer" strategy during the balance task. Further work needs to be done to validate seated distance reached (forward or lateral) as a measure of postural control. An interesting finding was that distance reached was not significantly different between patients with and without head righting reaction when reaching both forwards and to the side. In fact for one patient demonstrating a head counter-balancing movement on the lateral reach it was noted by the researcher when rating the HAT that the patient hardly reached at all, reaching only 13cm.

4C.1.3 Aim 3: To gain an understanding into the patient's perception of difficulty experienced with head activity following stroke

Only two patients reported difficulty moving their heads at assessment one and by assessment two and three none of the patients described difficulty moving their heads. In contrast, relatively high proportions of patients reported headaches and episodes of dizziness and these symptoms continued throughout the assessment period. In addition, three quarters of the patients described difficulty with their balance since their stroke. This proportion did not decrease at assessment two, but reduced to half at assessment three. It was noted by the researcher that around assessment two, with the increasing challenges of rehabilitation as many patients began to get back on to their feet, patients' awareness of their balance deficit seemed to increase.

Looking at the results it was apparent that a discrepancy existed between the rating of head activity with the HAT, and patients' perception of any difficulty with head activity. Patients typically described no difficulty with head activity yet demonstrated abnormal head activity. This could be seen to challenge the validity of the tool, and more broadly, it questions the concept that an intervention should be developed to optimise head activity following acute stroke. There were, however, problems associated with asking patients questions about their head activity. Firstly, it could be argued that it is too complex a concept to expect patients to understand. Head position and movement is not commonly discussed on the ward, or in therapy as a problem (unlike arm or leg movement). In fact, head activity is not generally discussed in life, and we lack the words to describe head activity in everyday language. One possible reason that head activity is not normally discussed is that the function of head activity is not usually directly related to goal achievement. This again is in contrast to the arm or leg. Secondly, in questioning patients about their head activity and related functions it is also possible that patients were not willing to acknowledge a further as yet unidentified problem when they already felt they had enough problems.

4C.1.4 Aim 4: To identify any relationships between head activity and classification of stroke, ADL ability, level of motor and sensory impairment, balance, and the presence of neglect

4C.1.4.a Classification of stroke

A significant difference was found in the HAT scores of those with TACI and PICH, and those with POCI, LACI, and PACI, those with TACI and PICH having a median HAT score of two at week one, and those with POCI, LACI, and PACI a median HAT score of seven. Smith and Baer (1999) found those with TACI and PICH took longer to achieve mobility milestones including the early milestone of independent sitting balance. The median number of days since stroke to achieve independent sitting balance for those with POCI, LACI, and PACI was the day of stroke, compared to those with PICH and TACI of 6.5 and 11 days respectively.

4C.1.4.b Severity of stroke

Despite the small size and limited variability of the sample the total HAT score at assessment one was significantly associated with Barthel Index score, Rivermead Motor Assessment Scale, Berg Balance Scale, and the Nottingham Sensory Assessment. A lower HAT score was associated with more limited ADL ability, greater motor and sensory impairment, and greater balance impairment. Caution needs to be used when interpreting the results of the correlation of HAT score with BIT score as only two patients (patient nos. 1 & 3) had neglect at assessment one. A trend was evident to a significant difference and, looking at the raw data, the two patients with neglect were the only patients to score the minimum score on the HAT at assessment one. It is expected that with a larger sample size a significant correlation between HAT score and BIT score would be established, but further research is needed to confirm this. As very little work relating to head activity in patients following stroke has been described, comparisons with findings from other studies are not possible.

4C.1.5 Aim 5: To profile the changes in head activity during the first six weeks following acute stroke

The three assessments in the first six weeks following stroke were chosen in an attempt to enable change in head activity to be described in the very acute phase of recovery, when abnormalities of head activity are most likely to demonstrated. The timing of assessments in this study; the end of weeks one, three, and six, is the same as those used by Taylor et al. (1994) in a prospective study of trunk symmetry following acute stroke. In addition, week six has been used widely as an assessment point in studies investigating recovery following acute stroke (e.g. Wade et al., 1985; Partridge et al., 1993; Morgan P., 1994; Smith et al., 2001). A significant increase in all outcome measure scores (Barthel Index, Rivermead Motor Assessment, Nottingham Sensory Assessment, Berg Balance Scale, and Behavioural Inattention Test) over the six-week assessment period was found. This was as expected despite the small sample size, as most patients with stroke show considerable recovery of function over the first few weeks following stroke (Kinsell and Ford, 1980; Andrews et al., 1981; Skilbeck et al., 1983; Wade et al., 1985).

4C.1.5.a Change in Head activity

<u>4C.1.5.a.i Total HAT score</u>

When looking at change in head activity over the six-week assessment period the sample was reduced to just eight. This limited the analysis, and caution must be taken when interpreting the results. Despite the small sample a significant increase in total HAT score was evident with increasing time since stroke. Within the sample there were however, different patterns within this trend, with some patients showing no change in HAT score over the six weeks, others showing a steady increase, and others showing a more marked increase. With so few patients, the different patterns could not be categorised or patients grouped into categories. However, it is hoped that the individual patient profiles presented in Section 4B.4 go some way to illustrating the variability within this sample, but also highlight the possibility that with greater numbers a number of groups could be identified in terms of initial total HAT score, and early change in HAT score. It was of interest whether a pattern was evident of patients achieving a certain HAT score prior to discharge home. A trend was evident that patients discharged had high HAT scores; of the five patients discharged home within the six-week study period HAT scores ranged from seven to ten with a median score of nine at their assessment prior to discharge. However, other patients with high scores were not discharged. Care has to be taken in interpreting these scores as time of discharge varied from patient to patient and was dependent on more than physical outcome, such as the environmental and social circumstances of the patient's home.

4C.1.5.a.ii Ratings for individual tool items

It was apparent that not only did none of the total HAT scores decrease over the assessment period, individual tool items that were rated as being achieved by patients at assessment one or two were also rated as being achieved at subsequent assessments. For example patient number 13 consistently achieved counterbalancing with the head during both reaching tasks at assessments one, two, and three. In addition they achieved an upright head during the sitting task at assessment two, and maintained it at assessment three. Such continued achievement of a tool item, once attained, could be argued to be an indication of test–re-test reliability. It suggests that if a tool item was rated as not achieved it was either consistently not achieved, or inconsistently achieved (not being achieved at the time of the assessment but acknowledging that the assessment is a 'one-off'). On the other hand, if a tool item was rated as achieved, the results suggest that it was so consistently (as it continued to be rated as achieved at subsequent assessments). This would be an acceptable level of test–re-test reliability if it were to be proven, as inconsistent achievement and consistent non-achievement both require intervention if the goal of consistent achievement is to be reached.

4C.1.5.a.iii Hierarchy of scoring

Although the limited sample size resulted in some categories remaining unused and that the numbers rated for a single category for a tool item being extremely small, evidence emerged of patterns of hierarchical rating within the HAT as a whole, and within individual tasks. From the upright sitting results it can be seen that an upright trunk posture was a prerequisite for an upright head posture. This meant that no patient corrected with his or her head for a non-upright trunk, i.e. none of the patients demonstrated a righting reaction in upright sitting. Although position of the trunk was not rated, looking at the video-recordings it was apparent that the head and trunk varied from the upright consistently in the same direction in the frontal plane as if the head was "locked onto" the trunk. A hierarchical scoring was expected on the reaching task with achievement of head counterbalancing on the forward reach prior to that on the lateral reach. However, one patient achieved lateral reach counterbalancing with the head prior to that on forward reach, and with the small study numbers it is not possible to suggest whether this patient goes against the trend, or whether no trend exists. Within the HAT as a whole, there was a trend towards achieving counterbalancing with the head during the reaching task last. This pattern was also seen for the healthy adults, and suggests that achievement of an upright head and trunk, and a coordinated movement pattern between head, trunk, and upper limb is less challenging than being able to dissociate head and trunk movement to demonstrate a head righting reaction.

4C.1.5.a.iv Relationship between HAT score and functional outcome

The results of this study revealed no significant difference in ADL ability, motor impairment, or balance control at six weeks, between those with an initial low HAT score and those with initial high scores. On close scrutiny of the results it was apparent that there was a difference between the two groups other than the value of the initial HAT score. The patients in the low HAT scoring group were younger and had had more severe strokes. With only four patients in each group no conclusions regarding these findings can be made. In this study, too few patients had data for all three assessments (n=8) to split the sample into more than two groups, those with low (lower than the median), and those with high initial HAT score. This prevented separate analysis of those who had an initial low HAT score but whose score improved between the first and second assessment. In a study by Sandin and Smith (1990), looking at the value of sitting balance in the prediction of functional status at discharge, a significant difference in functional outcome was found between those with initially good sitting balance, those with sitting balance that improved, and those with poor sitting balance. The group whose sitting balance improved having a higher Barthel Index score than the group whose sitting balance did not improve. The authors stress the importance of identifying serial functional tasks that can be evaluated that could indicate which patients would do well during stroke rehabilitation. In order to look effectively at the impact of initial HAT score, or early rate of change in HAT score on functional outcome, a larger sample would be needed that included those with more severe stroke, and those who were least affected.

4C.1.6 Limitations of the study

4C.1.6.a Sample

For both the healthy adult and patient studies the small size of the samples limit the conclusions that can be drawn from the results. For the healthy adult sample the reliance on self-declaration of exclusion criteria by the participants leaves the possibility that some may have had undiagnosed or may not have disclosed exclusion criteria. As with any healthy adult sample how healthy the sample really is, is questionable. The patient study aimed to recruit 20 patients with first-ever acute stroke due to the limited time available for data collection. A sample of 16 was achieved. The limitations of sample size were compounded when looking at change in head activity over the six-week assessment period where the sample was reduced to eight as practical and financial limitations prevented the patients who were discharged prior to the final assessment from being followed up. Another crucial limitation to the study is the restricted diversity of the sample recruited. With the inclusion criteria and ethical approval necessitating informed consent and the passing of a cognitive screen, those with the most severe stroke were not recruited to the study. It is possible therefore, that those with the most abnormal head activity were excluded from the study. On the other hand, those not admitted for rehabilitation following their stroke, the least disabled patients, were also omitted from the study as only in-patients were recruited. Thus, the small sample lacked patients at the extremes of severity of stroke. Again this limitation is compounded when looking at the patients used to analyse change in head activity. The more able patients of the sample recruited were discharged before the second or third assessment and one of the most severely disabled patients was also lost to the change group after becoming unwell. The eight patients whose data were used to analyse the change in head activity over the six weeks can be considered as the middle band of an already limited sample.

4C.1.6.b Assessment timings

Efforts were made to assess patients in the very early stages of recovery following stroke; however, the six-week assessment period is acknowledged as a relatively short time frame in the recovery following acute stroke. Many patients will go on to make significant further recovery after six weeks and it is possible that significant changes in head activity could occur after this time. Failure to follow patients for longer also meant that associations between head activity and functional outcome later than six weeks could not be explored.

4C.1.6.c Test–re-test characteristics of the HAT

As test–re-test characteristics of the HAT have not been established it is not known whether a one-off performance of the HAT was reflective of the head activity that would be have been used if the patient were to perform the test again. This limitation of the HAT must be considered when interpreting the results from this study.

4C.1.6.d Underlying mechanisms of head and trunk control

A further limitation of this study is that although the head activity used by healthy adults and patients following stroke has been described in terms of movement patterns, no attempt has been made to investigate the underlying mechanisms of abnormal head and trunk control following stroke. This was beyond the scope of this work, but knowledge of the mechanisms that underpin head activity and postural control is vital for a scientific basis for stroke rehabilitation.

4C.1.6.e Measurement of seated distance reached

Unfortunately in this study the height of the subjects was not recorded. Recent work by Stack (2003) looking at standing functional reach expressed distance reached as a percentage of the individual's height (height-adjusted functional reach). Distance reached expressed as a percentage of height, would allow for more accurate comparison between groups, by taking height (and arguably gender) into account. In the study presented here participants demonstrated a single reach in each direction. A single reach was used, as the primary purpose of the reach was the assessment of the presence of a counterbalancing reaction with the head as part of the HAT. Although a possible weakness of this study is that subjects only complete a single reach in each direction, the variations reported by Sinclair (1998) during a seated forward reach repeated three times were small.

4C.1.6.f Suggestions to overcome the limitations in future work

The limitations present within these two studies have highlighted a number of recommendations for future research. These recommendations are presented in Section 6.9 with those identified from the other studies presented within this thesis.

4C.2 Summary

These are the first studies in which the newly developed HAT was used. A description, and the range of head activity demonstrated by a small sample of healthy adults aged over 40 years of age are presented. A trend was evident towards 'typical', task-specific head activities, with very limited variability demonstrated within the sample. The HAT was used successfully in the acute clinical setting, and the patient study findings have gone some way to answer the research questions arising from the hypotheses stated at the beginning of the thesis. Findings from this study support the hypotheses that abnormal head activity is common following stroke, and abnormal head activity is associated with type and severity of stroke. Studies using larger samples of patients over a longer time frame are needed to further explore head activity following stroke, and to describe the impact of abnormal head activity on functional outcome. In the following chapter (5), three-dimensional motion analysis data is used to provide an in-depth description of the head activity demonstrated by patients and healthy adults during the most dynamically challenging of the HAT tasks, the seated lateral reach. It is hoped that the detailed results from the study will complement the gross rating of head activity obtained from using the HAT in the studies presented in this chapter.

Chapter 5

Three-dimensional motion analysis of the head activity used during a seated lateral reach

5.1 Introduction

A prerequisite for the development of successful, effective, rehabilitation therapies following stroke is the understanding of the mechanisms underlying the motor deficits common to these patients (Cristea and Levin, 2000). As previously highlighted, characterising the head activity demonstrated by patients following stroke is a necessary first step to furthering knowledge of the effect of stroke on head activity. In Sections 4A and 4B, descriptions of the head activity used by healthy adults and patients, as rated by the HAT, were reported. In this chapter, the three-dimensional motion analysis data collected during the testing of the external validity of the HAT (Section 3A) are used to give a more detailed description of the head and trunk rotations used during the seated lateral reaching task. The motion analysis data, reported by Polaris, have been analysed, and the movement patterns used by those with and without stroke are described.

5.1.1 Background

Controlled voluntary movement requires a coordinated action of the prime movers while activating appropriate muscles to maintain postural stability. The constant postural adjustments that accompany voluntary movement serve to maintain equilibrium of the body, and control the relationship of body segments (Massion, 1984). The existence of a large number of ways to combine individual components to generate voluntary movement allows the individual to perform goal-directed movement in a variety of ways, according to environmental and task conditions (Kelso et al., 1993; Ma and Feldman, 1995).

Following stroke, impairment of motor function is one of the most common problems encountered by the patient (Wade et al., 1985) and was discussed in detail in Section 1.2.2. As a result of a deficit in motor function, the selection and control of specific movements from the repertoire of possible movements is frequently impaired. Thus, following stroke, the patterns of movement seen are frequently constrained to behave in a limited way.

The majority of studies investigating the three-dimensional movement patterns used following stroke have looked at gait, stepping, and rising from sit to stand. These tasks all require the achievement of the mobility milestones of standing, stepping, or walking. For some patients, particularly those with PICH and TACI, this can take weeks (Smith and Baer, 1999), and for a few, these milestones are never achieved. Despite sitting balance being achieved earlier in the recovery process, few studies have looked at the movement patterns used by patients following stroke in sitting. Recently however, some studies have reported the movement patterns (including those of the trunk) used in sitting during upper limb function. These studies will be reviewed in the following paragraphs.

The study reported by Campbell et al. (2001) was discussed in detail in Section 1.4.4. This study is the only study to date known to report three-dimensional motion analysis data of head position and movement following stroke during a functional task in sitting. The results from the study suggest that patients have difficulty dissociating segmental movements of the head, trunk, and pelvis during a dynamic seated reaching task.

Michaelsen et al. (2001) compared the movement strategies of 11 patients with stroke and 11 healthy individuals, during reaching in sitting with and without the trunk restrained. During unrestrained reaching, excessive trunk recruitment and reduced elbow and shoulder movements were correlated with the degree of stroke severity. During trunk restraint ranges of movement at the elbow and shoulder increased in both groups. In addition elbow and shoulder inter-joint coordination improved. The authors suggest that without constraint the trunk was used to compensate for limitations of upper limb movement control. The use of trunk restraint allowed patients to make use of movement strategies that are present but not recruited during unrestrained reaching.

In a study by Cristea and Levin (2000) the pointing movements of nine patients with left hemisphere stroke and nine healthy controls were compared. Arm movements in the patients were longer, more segmented, more variable, and had larger movement variables. All but one subject involved the trunk to accomplish the task. Trunk movement was not seen in the control group. Cristea and Levin (2000) suggest the increased use of the trunk may compensate for limitations in control of active joint ranges of the affected upper limb.

Messier et al. (2004) quantified trunk movement and lower-limb weight bearing during a seated dynamic trunk flexion (forward lean) to touch a target at 66% of arm length with the forehead. The target was midline and 45° to each side. Optotrack infrared markers were placed on gleno-humeral joints and greater trochanters. The authors compared the movement patterns used by 15 patients with sub acute and chronic stroke and 13 healthy adults. Time since stroke ranged from 3 to 132 months. Amplitude of trunk flexion and speed of movement were similar for the two groups but patients demonstrated less COP displacement especially in the anterior direction, maintaining more weight on their buttocks and less on their feet. The authors propose that the anterior trunk flexion demonstrated by patients was executed more by upper trunk flexion with very little anterior pelvic tilt. However, the relative contribution of trunk segments cannot be confirmed, as the subjects wore no pelvic markers.

The relatively few studies, and the limitations within them, severely restrict the conclusions that can be drawn form the work carried out to date on the movement patterns used by patients following stroke in sitting. The limitations of the studies include the very small sample sizes used, the absence of aged matched control samples, the lack of transparency in the patient selection procedure, and the large range of time since onset of stroke – for example, of the 15 patients used in the study by Messier et al. (2003) the time since stroke ranged from 3-132 months. Small numbers also mean that studies cannot look at difference in movement patterns used by those with different types and severity of stroke, or at different stages in the recovery period. Of the few three-dimensional movement analysis studies that have looked at movement patterns used in sitting following stroke, the main emphasis to date has been on upper limb activity. Although, some of these studies do report some trunk movement, only the study by Campbell et al. (2002) includes analysis of movement or position of the head. Dissociation of head position and movement from the trunk is arguably not sound, as movement of the head takes place at the cervical spine, which is part of the trunk, and trunk movement results in head movement in relation to the environment, unless accompanied by active head counterbalancing.

The studies reviewed above, despite their limitations, do provide valuable information about the movement patterns used by people with and without stroke during simple functional activities in sitting. It is this type of activity that is frequently used during the early treatment of patients following stroke. Further studies looking at the movement patterns of patients during simple tasks in sitting, that address the limitations raised by the studies carried out to date are required. In particular studies in the very acute phase of recovery, including analysis of head and trunk activity, are required.

5.1.2 Study aims

The aim of this study was to describe in detail the head and trunk movement patterns used by a small number of subjects with and without acute stroke during a seated lateral reach. The movement strategies used will be described in terms of:

- Starting position
- Patterns of head and trunk rotations
- End position
- Presence of head counterbalancing reaction
- Continuity of movement
- Angle of trunk roll
- Distance reached

5.2 Methods

5.2.1 Participants

The participants described in this work were the healthy adult and patient samples used in the external validity study presented in Section 3A. The recruitment of the healthy adult and patient samples has been described in Sections 4A.2.2 and 4B.2.2 respectively.

5.2.2 Procedure

All sets of motion analysis data for the lateral reach task, collected for validity testing, were re-analysed. Details of the Polaris equipment set-up and data collection procedure are described in Section 3A Sections 3A.3.3 to 3A.3.4 The distance reached data for the seated lateral reach were re-analysed for these samples. Details of the measurement of distance reached are outlined in Section 4A.2.3.c.i. In addition, the clinical data recorded in the study undertaken in Section 4B were reanalysed for the patient sample. Details of the measures are described in Section 4B.2.3.c.i.

5.2.3 Data analysis

The Polaris motion analysis results are reported as *Roll, Pitch* and *Yaw* rotations of each of the three marker configurations (the head, the trunk, and the fixed room reference marker configurations). Graphical representations of the rotations of the head marker configuration relative to the trunk marker configuration, the head marker configuration relative to the fixed reference, and the trunk marker configuration relative to the fixed reference were produced. The researcher examined the graphs visually, and described and categorised the head and trunk rotations. An example of the graphical output of the Polaris data is shown in figure 5.1. The rotations and their direction are detailed in the key.

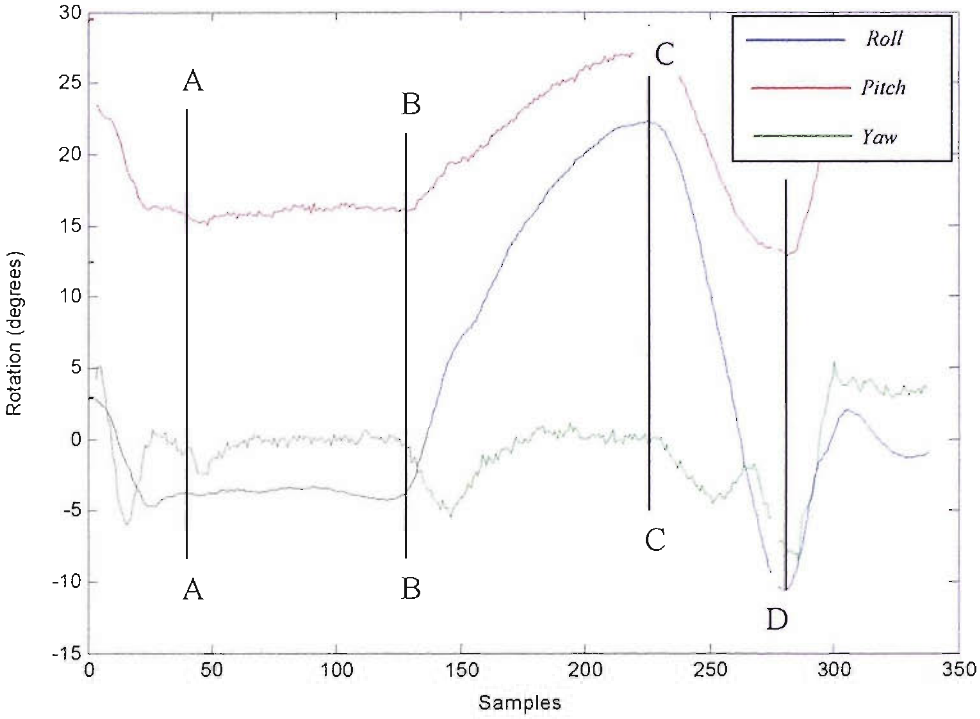

Figure 5.1 Example of the graphical output of Polaris data

KEY:

Roll +ve = right side flexion
-ve = left side flexion

Pitch +ve = flexion
-ve = extension

Yaw +ve = left rotation
-ve = right rotation

A ——— **A**	Start point of starting position
B ——— **B**	End of starting position/ start of reach
C ——— **C**	Point of maximum reach
D ——— **D**	End of reach return

The following features of the lateral reach demonstrated by each participant are described:

Starting position: The position of the head and trunk, prior to the start of the reach, relative to the fixed room reference was categorised as being upright or not as defined by the Polaris boundary definitions of 'upright head' and 'upright trunk' (as used to test the external criterion validity of the HAT in Section 3A). The definitions of 'upright trunk' and 'upright head' are the same as presented in table 3A.1 but are repeated in table 5.1 to assist with comparison with the Polaris graphical output.

Trunk upright	Yes	Trunk relative fixed: At a single time point a position is achieved of ≤ 23° pitch from neutral, ≤ 6° roll from neutral, and ≤ 5° yaw from neutral
	No	Trunk relative fixed: Failure to meet all three "YES" category boundary criteria
Head upright	Yes	Head relative fixed: At a single time point a position is achieved of ≤ 10° pitch from neutral, ≤6° roll from neutral, and ≤ 5° yaw from neutral
	No	Head relative fixed: Failure to meet all three "YES" category boundary criteria

Table 5.1 Definitions of upright trunk and upright head

Patterns of head and trunk rotations: The presence and direction of head *roll*, *pitch* and *yaw* relative to the trunk, trunk *roll*, *pitch* and *yaw* relative to the fixed reference, and the resulting head *roll*, *pitch* and *yaw* relative to the fixed reference was described.

End position: The position of both the head and trunk relative to the fixed room reference at the end of the reach was categorised as "overshooting" or not. "Overshoot" was defined as 'on the return from the reach the head *and* trunk position goes beyond the position achieved at the start of the reach'.

Presence of head counterbalancing reaction: The presence of a counterbalancing reaction with the head was categorised using the Polaris boundary definitions for 'counterbalancing with the head' for the lateral reach (as used to test the external criterion validity of the HAT in Section 3A). The definition of 'counterbalancing with the head' is the same as presented in table 3A.5 but is repeated in table 5.2, again to assist with comparison with the Polaris graphical output.

Counterbalances with head on lateral reach	YES	Head relative trunk: ≥ 8° roll from the starting position in the opposite direction to trunk roll. Head relative fixed: At the peak of the reach (maximum trunk roll) head roll is ≤ +/-10° from neutral.
	NO	Failure to meet both "YES" category boundary criteria

Table 5.2 Definitions of counterbalancing with the head on the lateral reach

Continuity of movement: Trunk roll relative to the fixed reference was categorised as "continuous" or "staged". "Staged" was defined as a non-smooth achievement of maximum trunk roll resulting in at least one marked step in the graphical output of trunk roll from the start to the peak of the reach. "Continuous" was defined as not meeting the "staged" definition, i.e. the absence of any steps in the graphical output of trunk *roll* from the start to the peak of the reach.

Angle of trunk roll: The amplitude of trunk roll was measured from the start, to the peak of the reach (maximum trunk roll).

Distance reached: The distance reached was measured in cm using a height-adjustable portable metre rule. Distance reached was the difference between the starting position of the proximal inter-phalangeal joint of the third finger along the metre rule and the position at the point of maximum reach (see Section 4A.2.3.c.i for more details of measurement of the seated lateral reach).

5.3 Results

5.3.1 Participants

5.3.1.a Healthy adults

The motion analysis data of the six healthy adults (recruited to test the validity of the HAT) were re-analysed. The sample comprised one male and five females, with a median age of 56. All were right handed and performed the lateral reach with their dominant right hand. A description of the healthy adult sample is presented in table 5.3. Polaris motion analysis data were available for all six participants.

Age	Gender	Dominant hand	Reaching arm
Median 56 Min-max 49-66	1 Male 5 Female	6 Right	6 Right

Table 5.3 Description of healthy adult sample

5.3.1.b Patients with acute stroke

The motion analysis data of six of the seven patients recruited to test the validity of the HAT were re-analysed. Technical difficulties meant that one patient's lateral reach data were of too poor a quality to analyse. The sample comprised of four males, and two females, with a median age of 77. All but one of the patients was right handed. All performed the lateral reach with their unaffected (right) arm, meaning that one patient used their non-dominant arm to reach. A description of the patient sample is presented in table 5.4.

Age	Gender	Dominant hand	Hemiplegic arm	Reaching arm
Median 77 Min-max 64-84	4 Male 2 Female	5 Right 1 Left	6 Left	5 Dominant (all Right) 1* Non-dominant (Right)

Table 5.4 Description of patient sample

A clinical assessment was carried out within 24 hours of the recording of the Polaris data with the battery of tests used in the study presented in Section 4B and described in detail in Section 4B.2.3.c.i. Two of the patients had lacunar infarcts, two partial anterior infarcts, and two primary intracerebral haemorrhages. The median number of days since stroke was 24 with a range from 19 to 25. HAT scores ranged from four to nine with a median score of 7.5. Barthel Index (BI) scores ranged from 10 to 18 with a median score of 14. Rivermead Motor Assessment total scores ranged from nine to thirty with a median score of 20.5. Berg Balance Scale (BBS) scores were also wide ranging (8-37), with a median value of 21. Nottingham Sensory Assessment (NSA) scores ranged from 41-64, and Behavioural Inattention (BIT) Scores from 135-146, indicating that none of the patients had unilateral neglect. The patient clinical data are presented in table 5.5.

	OCSP stroke classification	Number of days since stroke	HAT score	BI score	RMA score	BBS score	NSA score	BIT score
Patient no. 1	PACI	23	9	15	22	30	60	143
Patient no. 2	PACI	19	6	16	21	25	64	145
Patient no. 3*	PICH	25	5	10	9	8	52	135
Patient no. 4	LACI	25	9	10	15	17	41	145
Patient no. 5	LACI	20	9	18	30	37	64	146
Patient no. 6	PICH	25	4	13	20	16	33	144

Table 5.5 Patient clinical data

5.3.2 Movement patterns

The results for each of the movement patterns analysed during the seated lateral reach are presented in turn. For each movement pattern the summary results for the two samples, healthy adults and patients with stroke, are described. Details of individual results from both the healthy adult and patient samples are presented with illustrative graphs where appropriate. The relationship between the different categories of movement pattern for each sample is then described.

5.3.2.a Starting position

5.3.2.a.i Healthy adult starting position

Three out of the six healthy adults started the reach from a starting position of 'upright head' *and* 'upright trunk'. Two demonstrated an 'upright trunk' but 'non-upright head'. The remaining subject (healthy adult no.1) started the reach with a non-upright head *and* a non-upright trunk. The starting position of each healthy adult is summarised in table 5.12 (Section 5.3.3).

Healthy adult no. 3: *The reach was* started from a position of 'upright head' and 'upright trunk', both head and trunk *roll, pitch* and *yaw* rotations were all within the boundaries set for the upright position (as defined in table 5.1). The pattern of rotations for the trunk relative to the fixed room reference is shown in figure 5.2. Between points A and B it can be seen that trunk *pitch* was ≤ 23°, *roll* ≤ 6°, and *yaw* ≤ 5° from neutral.

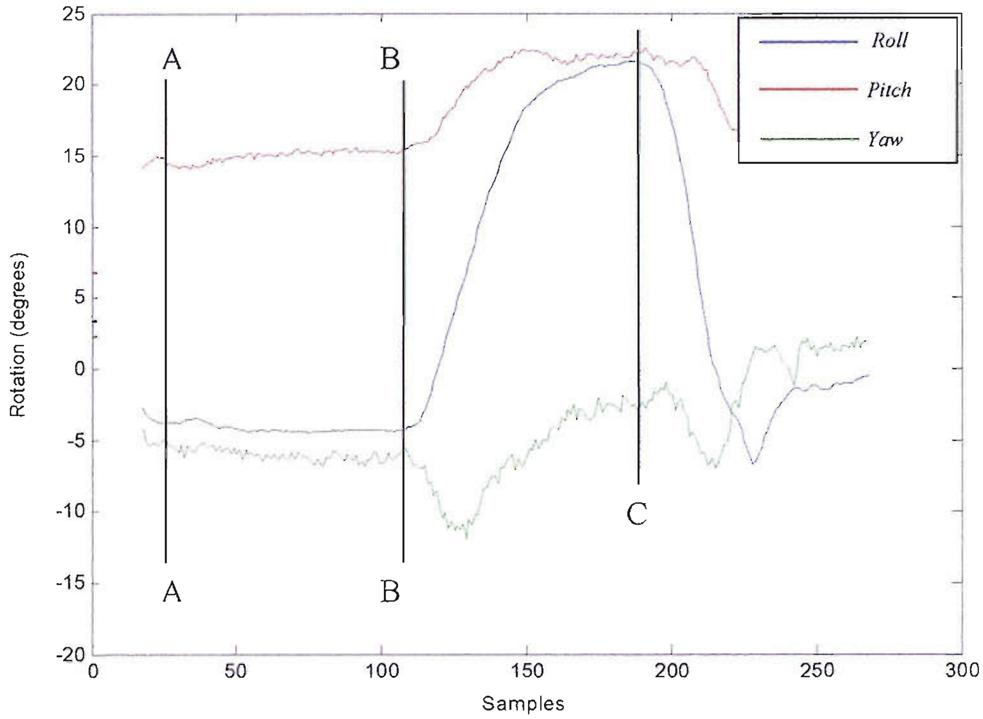

Figure 5.2 Healthy adult no. 3 trunk relative to fixed reference

The pattern of rotations for the head relative to the fixed room reference for healthy adult no. 3 is shown in figure 5.3. Between points A and B it can be seen that head was *pitch* $\leq 10°$, *roll* $\leq 6°$, and *yaw* $\leq 5°$ from neutral.

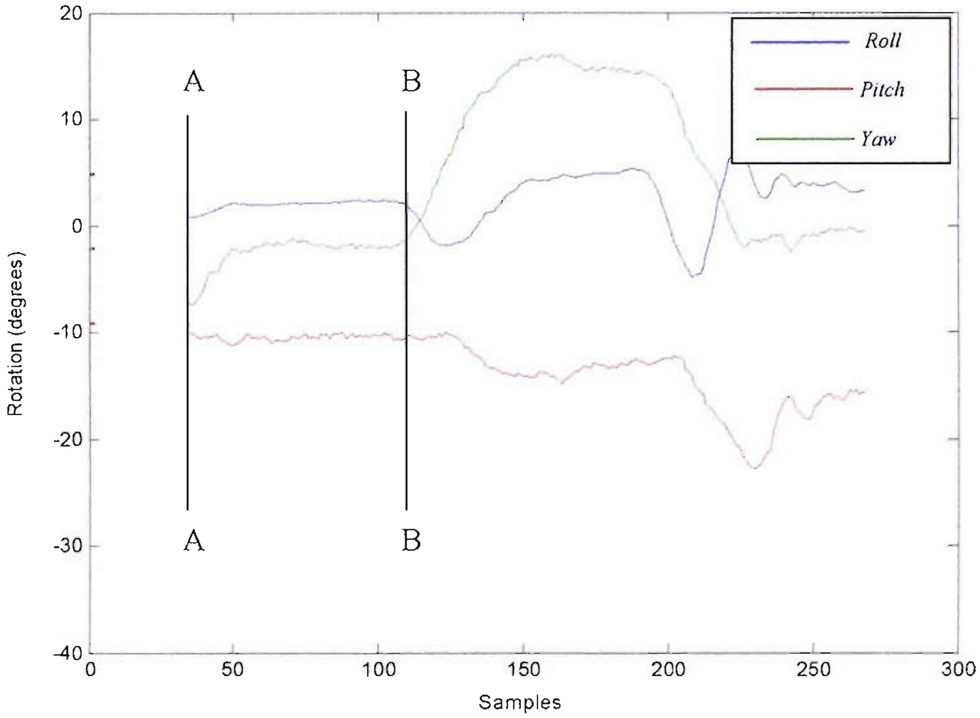

Figure 5.3 Healthy adult no. 3 head relative to fixed reference

5.3.2.a.ii Patient starting position

Only two out of the six patients started the reach from a position of 'upright trunk' (patient no. 2 and patient no. 3). Of the four patients starting from a non-upright trunk position three had a position of trunk *yaw* in the opposite direction to their hemiplegic side, in the same direction as the reach. The remaining patient had a position of trunk *roll* towards their hemiplegic side (in the opposite direction to the reach). None of the patients started the reach from a position of 'upright head'. Four of the patients had a position of head *yaw* in the opposite direction to their hemiplegic side (towards the reach), one of these patients also had negative head *pitch* (extension), and one had negative head *pitch* and head *roll* away from their hemiplegic side but towards the reach. One patient had a position of negative head *pitch*. The remaining patient had head *yaw* and *roll* towards their hemiplegic side (on the opposite direction to the reach). The starting position of each patient is summarised in table 5.13 (Section 5.3.3).

Patient no. 6: The reach was started from a position of non-upright head *and* trunk. The pattern of rotations for the trunk relative to the fixed room reference is shown in figure 5.4. The trunk was defined as non-upright as between points A and B trunk *roll* was >6° in the opposite direction of the reach.

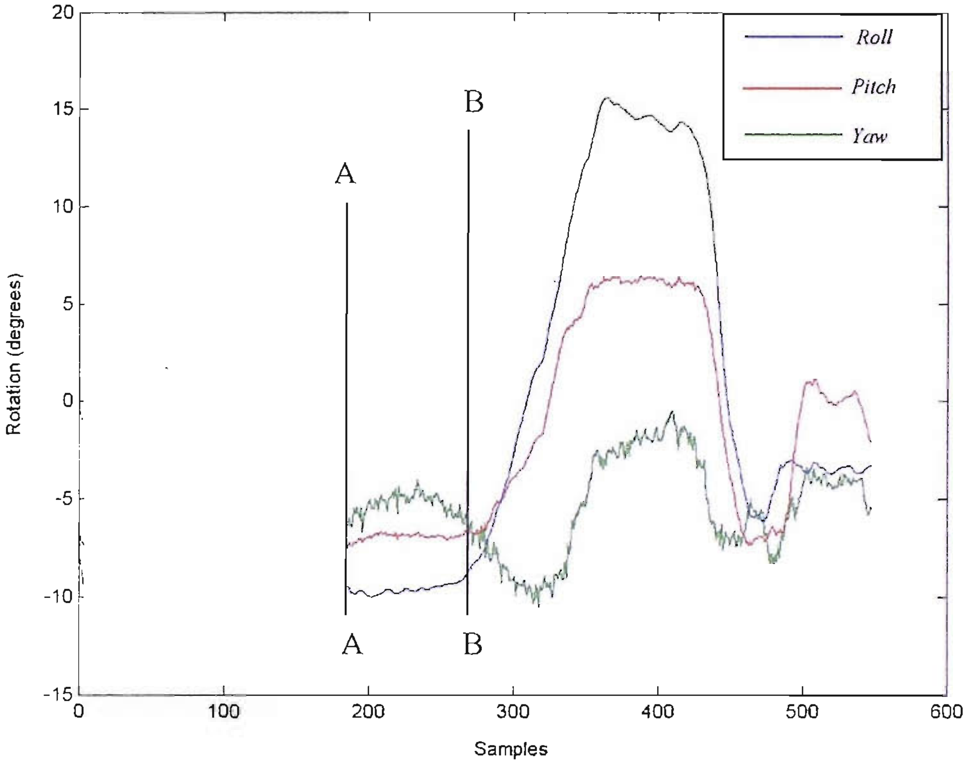

Figure 5.4 Patient no. 6 trunk relative to fixed reference

The pattern of rotations for the head relative to the fixed room reference for patient no. 6 is shown in figure 5.5. The head was defined as non-upright as between the points A and B head *pitch* -12° (extension) and *yaw* -11° (right rotation) were both outside the boundaries set for an upright head position.

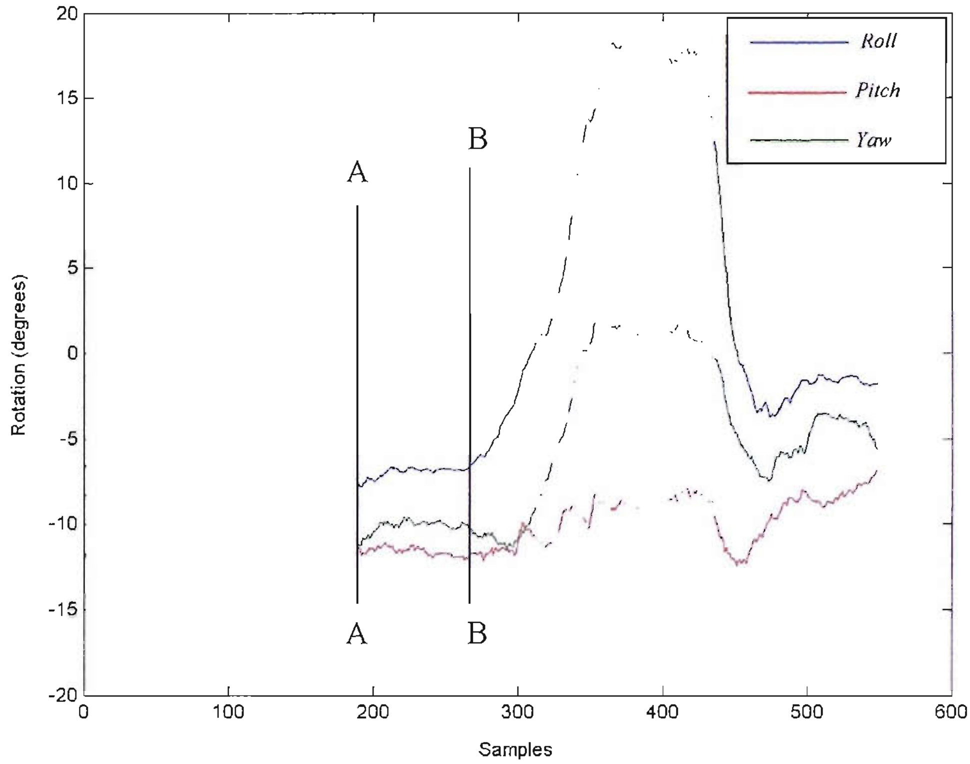

Figure 5.5 Patient no. 6 head relative to fixed reference

5.3.2.b Patterns of head and trunk rotations

5.3.2.b.i Healthy adult patterns of head and trunk rotations

Trunk relative to the fixed room reference

Table 5.6 summarises the pattern of trunk rotation relative to the fixed room reference demonstrated by each healthy adult. All healthy adults demonstrated trunk *roll* in the same direction to that of the reach. *Roll* was the largest amplitude of all the trunk rotations. All healthy adult participants demonstrated positive trunk *pitch* (flexion) accompanying the *roll*; with peak of trunk *pitch* occurring at approximately the same time as the peak of trunk *roll*. Three of the healthy adults used trunk *yaw* during the reach, and rotated their trunk in the opposite direction to the reach, again peak of trunk *yaw* occurred at approximately the same time as the peak of *roll* and *pitch*.

	Roll	*Pitch*	*Yaw*
1	Towards reach	+ve (flexion)	nil
2	Towards reach	+ve (flexion)	Away from reach
3	Towards reach	+ve (flexion)	Away from reach
4	Towards reach	+ve (flexion)	nil
5	Towards reach	+ve (flexion)	Away from reach
6	Towards reach	+ve (flexion)	nil

Table 5.6 Pattern of trunk rotations relative to fixed room reference (healthy adults)

Healthy adult no. 2: A typical pattern of trunk rotation was demonstrated, and the pattern of rotations for the trunk relative the fixed room reference is shown in figure 5.6. Between points B and C trunk *roll* was in the direction of the reach (right side-flexion) and was accompanied by positive trunk *pitch* (flexion) and trunk *yaw* in the opposite direction. The rotation of largest amplitude was trunk *roll*.

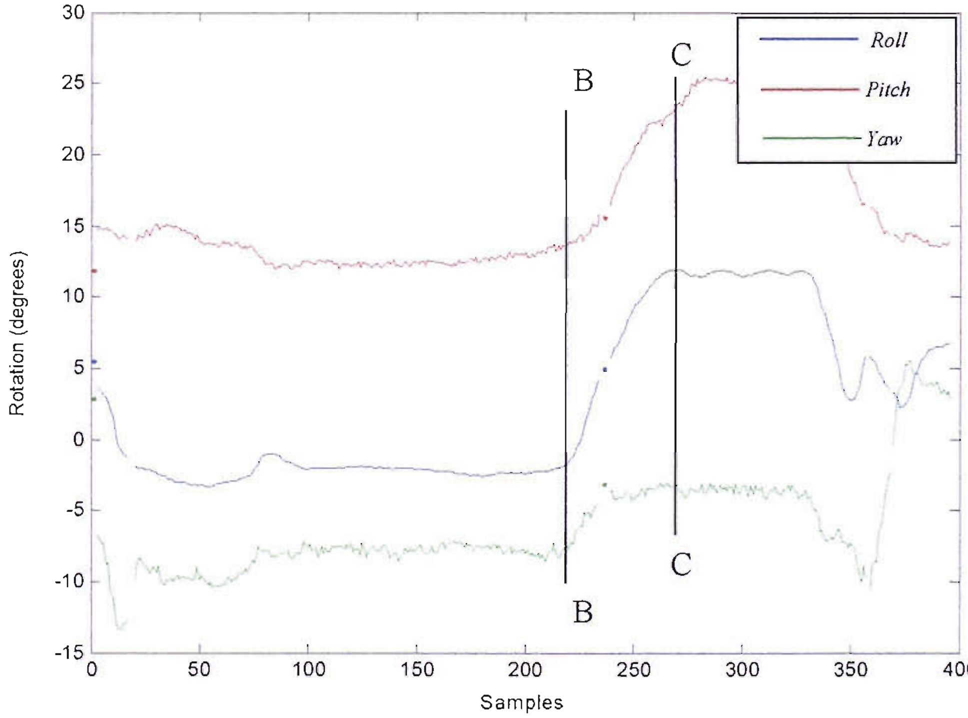

Figure 5.6 Healthy adult no. 2 trunk relative to fixed reference

Head relative to the trunk

Table 5.7 summarises the pattern of head rotation relative to the trunk demonstrated by each healthy adult. Five of the six healthy adults demonstrated the same patterns of head rotations relative to the trunk. Head *roll* was in the opposite direction to both the reach, and trunk *roll*. Head *yaw* was in the opposite direction to the reach, but in the same direction as trunk *yaw* (if demonstrated). Negligible, if any, head *pitch* occurred relative to the trunk, and a position of moderate head extension relative to the trunk was maintained throughout the reach. The remaining healthy adult (no.6) demonstrated minimal *roll* and *yaw* in the opposite direction of the reach, and minimal negative *pitch* (extension).

	Roll	*Pitch*	*Yaw*
1	Away from reach	nil	Away from reach
2	Away from reach	nil	Away from reach
3	Away from reach	nil	Away from reach
4	Away from reach	nil	Away from reach
5	Away from reach	nil	Away from reach
6	Minimal away	Minimal -ve	Minimal away

Table 5.7 Pattern of head rotations relative to the trunk (healthy adults)

Healthy adult no. 2: A typical pattern of head rotation relative to the trunk was demonstrated, and is shown in figure 5.7. Between points B and C it can be seen that head *roll* was in the opposite direction of the reach (left side-flexion), and was accompanied by head *yaw* away from the reach (left rotation), and maintenance of negative head *pitch* (extension).

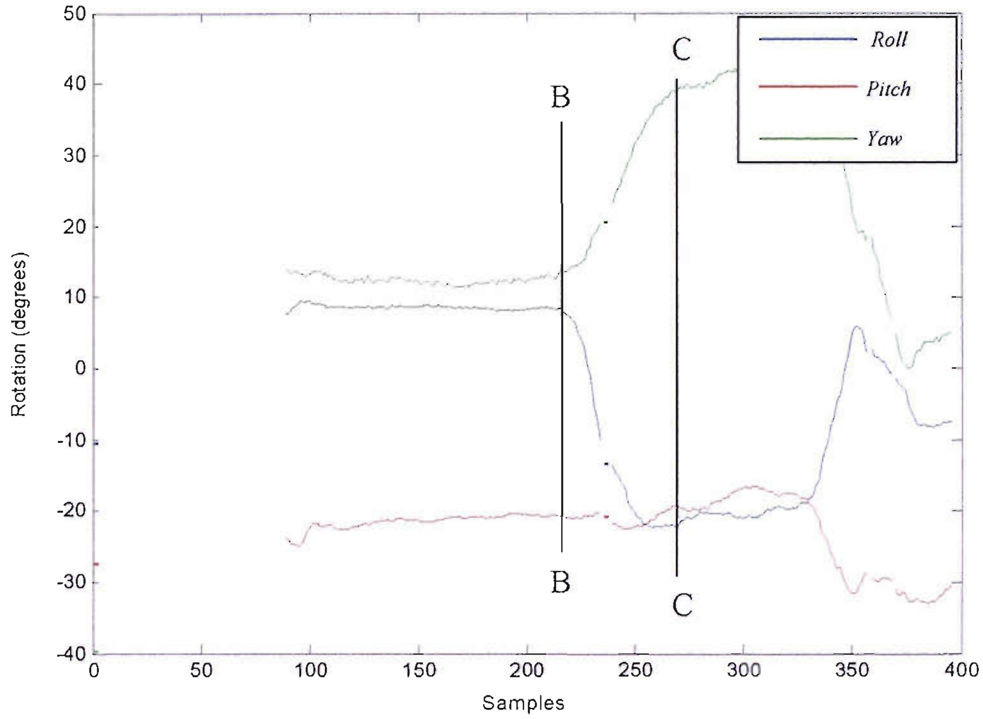

Figure 5.7 Healthy adult no. 2 head relative to trunk

Head relative to the fixed room reference

Table 5.8 summarises the pattern of head rotation relative to the fixed room reference demonstrated by each healthy adult. Rotation of the trunk with respect to the fixed reference and rotation of the head with respect to the trunk resulted in the following patterns of head rotations relative to the fixed room reference for the group of healthy adults: All healthy adults demonstrated head *yaw* in the opposite direction to the reach. All demonstrated minimal if any head *pitch* relative to the fixed reference, maintaining a position of slight head extension throughout the reach. A mixed picture was evident in terms of head *roll* relative to the fixed room reference. Three of the healthy adults demonstrated a small head *roll* away from the reach, one demonstrated a minimal amount of head *roll* in the same direction of the reach, and one participant demonstrated fluctuating head *roll* around the neutral position. Both of the healthy adults demonstrating either fluctuating *roll*, and *roll* towards the direction of the reach maintained head *roll* within 5° of neutral. The remaining participant demonstrated large amplitude of head roll (approximately 24°) in the same direction as the reach (and trunk).

	Roll	*Pitch*	*Yaw*
1	Minimal away	nil	Away from reach
2	Minimal away	nil	Away from reach
3	Fluctuating	Minimal -ve	Away from reach
4	Minimal towards	Minimal -ve	Away from reach
5	Minimal away	nil	Away from reach
6	Towards reach	Minimal +ve	Away from reach

Table 5.8 Pattern of <u>head</u> rotations relative to the fixed room reference (healthy adults)

Healthy adult no. 2: A typical pattern of head rotation relative to the fixed room reference was demonstrated and is shown in figure 5.8. Between points B and C a small amount of head roll in the opposite direction to the reach (left side-flexion) is accompanied by head yaw away from the reach (left rotation), and minimal head pitch maintaining slight head extension relative to the trunk.

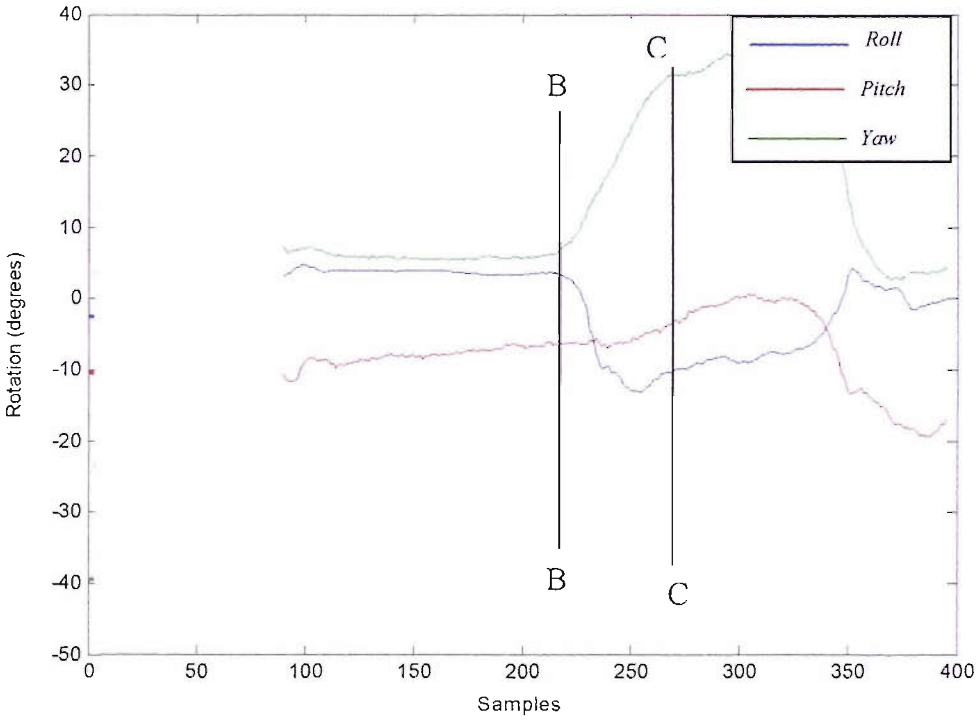

Figure 5.8 Healthy adult no. 2 <u>head</u> relative to fixed reference

<u>5.3.2.b.ii Patient patterns of head and trunk rotations</u>

Trunk relative to the fixed room reference

Table 5.9 summarises the pattern of trunk rotation relative to the fixed room reference demonstrated by each patient. All patients demonstrated trunk *roll* in the same direction as the lateral reach. Five out of the six patients demonstrated positive trunk *pitch* (flexion), with peak of trunk *pitch* occurring at approximately the same time as the peak of trunk *roll*. The remaining patient (no. 2) maintained a static position in terms of *pitch* throughout the reach. A mixed picture was evident with respect to amplitude and direction of trunk *yaw*. Two patients demonstrated trunk *yaw* in the opposite direction to the reach. Three patients demonstrated a mixed pattern of trunk *yaw*, initially rotating towards the reach, and then rotating away from the reach. The remaining patient did not demonstrate any trunk *yaw* rotation. Trunk *roll* was the rotation of largest amplitude for five of the patients, and for the remaining patient (patient no. 3) the largest amplitude of rotation was trunk *pitch*.

	Roll	*Pitch*	*Yaw*
1	Towards reach	+ve (flexion)	Fluctuates
2	Towards reach	nil	Fluctuates
3	Towards reach	+ve (flexion)	Minimal away
4	Towards reach	+ve (flexion)	nil
5	Towards reach	+ve (flexion)	Away from reach
6	Towards reach	+ve (flexion)	Fluctuates

Table 5.9 Pattern of trunk rotations relative to the fixed room reference (patients)

Patient no. 1: The pattern of rotations for the trunk relative the fixed room reference for patient no. 1 is shown in figure 5.9. Between points B and C trunk *roll* is in the direction of the reach (right side-flexion), and is accompanied by positive trunk *pitch* (flexion) and fluctuating trunk *yaw*. From the graph it can be seen that the rotation of largest amplitude was trunk *roll*.

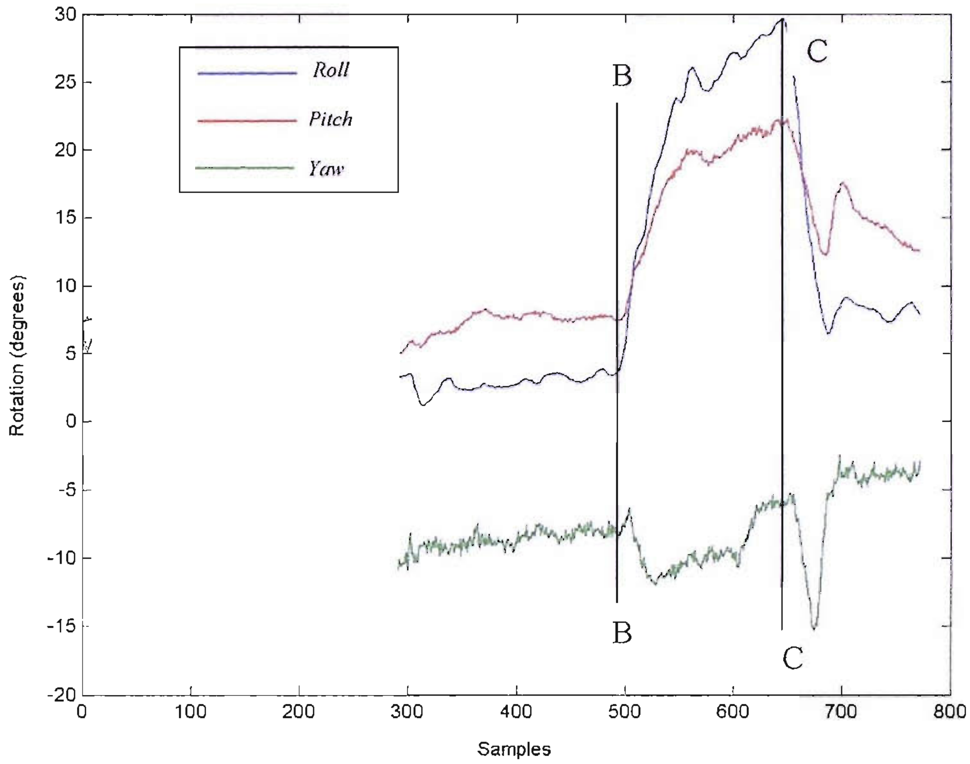

Figure 5.9 Patient no. 1 trunk relative to the fixed reference

Head relative to the trunk

Table 5.10 summarises the pattern of head rotation relative to the trunk demonstrated by each patient. Four out of the six patients demonstrated negative head *pitch* (extension) relative to the trunk. The remaining two patients maintained a static *pitch* rotation throughout the reach. Five of the patients demonstrated head *yaw* in the opposite direction to the reach, with the remaining patient demonstrating slight *yaw* rotation towards the reach (no. 6). A more mixed picture was evident when looking at head *roll* relative to the trunk. Three patients demonstrated minimal head *roll* towards the direction of the reach (in the same direction as trunk *roll*), one patient maintained a static head position in terms of *roll* and the remaining two patients demonstrated head *roll* in the opposite direction to the reach (opposite direction to trunk *roll*).

	Roll	*Pitch*	*Yaw*
1	Towards reach	-ve (extension)	Away from reach
2	Minimal towards	nil	Away from reach
3	nil	-ve (extension)	Away from reach
4	Away from reach	-ve (extension)	Away from reach
5	Minimal away	nil	Away from reach
6	Minimal towards	-ve (extension)	Minimal towards

Table 5.10 Pattern of head rotations relative to the trunk (patients)

Patient no. 1: The pattern of rotations for the head relative to the trunk for patient no. 1 is shown in figure 5.10. Between points B and C a small amount of head roll in the direction of the reach (right side-flexion) was demonstrated. Head *yaw* was in the opposite direction to the reach (left-rotation) and head *pitch* was negative (extension).

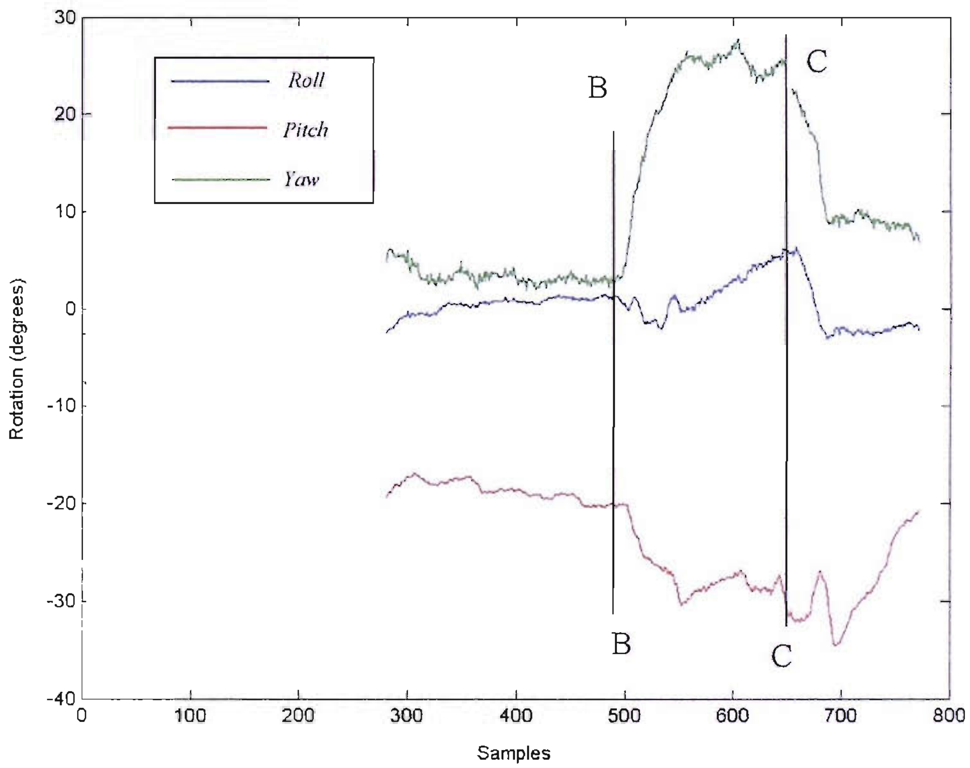

Figure 5.10 Patient no. 1 head relative to the trunk

Head relative to the fixed room reference

Table 5.11 summarises the pattern of head rotation relative to the fixed room reference demonstrated by each patient. Rotations of the trunk with respect to the fixed reference, and rotations of the head with respect to the trunk resulted in the following patterns of head rotations relative to the fixed room reference for the patient group. Five of the six patients demonstrated head *roll* relative to the fixed reference in the same direction as the reach (and trunk). The remaining patient (no. 4) maintained a static head position with respect to *roll* rotation relative to the fixed reference. Four of the six patients demonstrated no change in head *pitch* relative to the fixed reference during the reach. The remaining two patients (patients 2 and 4) demonstrated a small degree of negative head *pitch* (head extension). A mixed picture was evident in relation to degree and direction of head *yaw*. Four patients demonstrated head *yaw* in the opposite direction to the reach. One patient demonstrated a small degree of head *yaw* in the same direction as the reach, and the remaining patient showed fluctuating head *yaw* with head *yaw* initially in the same direction as the reach then away from the reach.

	Roll	*Pitch*	*Yaw*
1	Towards reach	nil	Away from reach
2	Towards reach	-ve (extension)	Away from reach
3	Towards reach	nil	Fluctuates
4	nil	Minimal -ve	Minimal towards
5	Towards reach	nil	Away from reach
6	Towards reach	nil	Away from reach

Table 5.11 Pattern of head rotations relative to the fixed room reference (patients)

Patient no. 1: The pattern of head rotations relative to the fixed room reference for patient no. 1 is shown in figure 5.11. Between points B and C a large amount of head *roll* in the direction of the reach (right side-flexion) is accompanied by a small degree of head yaw in the opposite direction to the reach (left rotation), and maintenance of head *pitch* in a position of moderate extension.

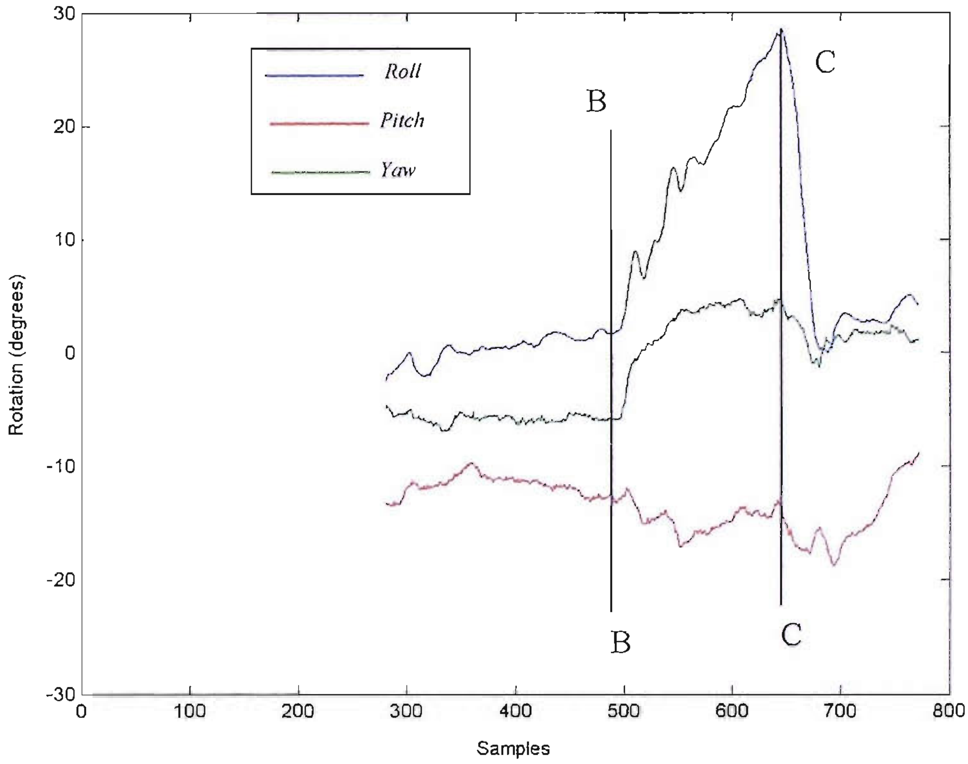

Figure 5.11 Patient no. 1 head relative to the fixed reference

5.3.2.c End position

5.3.2.c.i Healthy adult end position

Only one of the healthy adults (healthy adult no. 4) demonstrated an "overshooting" of the head and trunk on return from the reach. The remaining five participants returned to a position approximating their starting position. The end position of each healthy adult is summarised in table 5.12 (Section 5.3.3).

5.3.2.c.ii Patient end position

Only one of the patients (no. 5) demonstrated an "overshooting" of the head and trunk on return from the reach. The remaining five participants returned to a position approximating their starting position. The end position of each patient is summarised in table 5.13 (Section 5.3.3).

Patient no. 5: An "overshooting" of trunk *and* head *roll* was demonstrated. The pattern of trunk roll relative to the fixed room reference is shown in blue shown in figure 5.12. The starting position for trunk *roll* was neutral, increasing during the reach to 20°. On return from the reach (point D) trunk *roll* returned ***beyond*** the position at the start of the reach, to -5°, before increasing again to 2°.

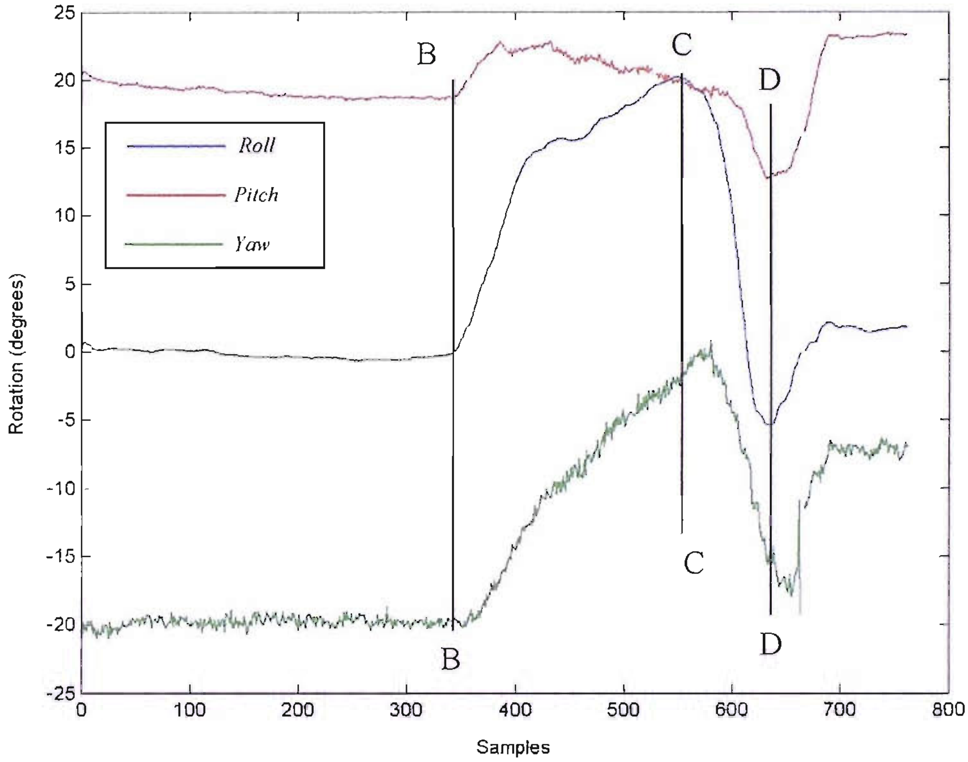

Figure 5.12 Patient no. 5 <u>trunk</u> relative to the fixed reference

The pattern of head roll relative to the fixed room reference is shown in blue in figure 5.13. The starting position of head roll was 7°, rising to a peak of 17° during the reach, then returning to a position (point D) beyond that of the starting position, -4°, before increasing to 3°.

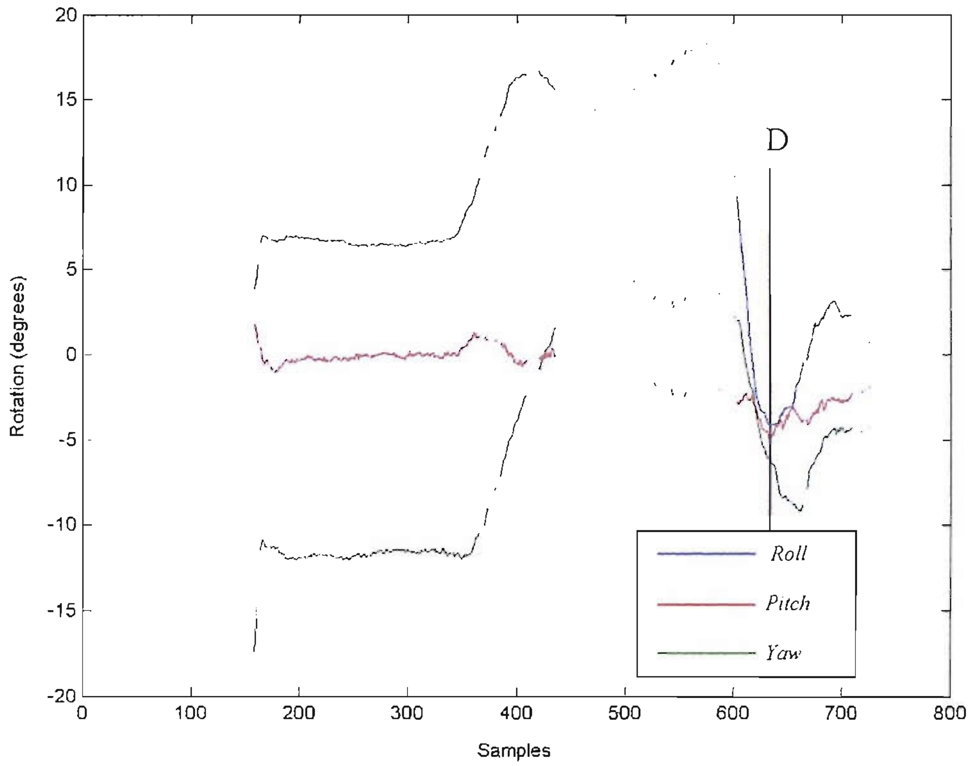

Figure 5.13 Patient no.5 <u>head</u> relative fixed reference

5.3.2.d Head counterbalancing reaction

<u>5.3.2.d.i Healthy adult head counterbalancing reaction</u>

Five out of the six healthy adults demonstrated a counterbalancing of the head with respect to the trunk in the frontal plane. The remaining participant (healthy adult no. 6) failed to meet the Polaris boundaries set for "counterbalancing with the head" for head *roll* relative to the trunk, or head *roll* relative to the fixed room reference, as described in table 5.2. However, all participants maintained a position of slight head extension relative to the fixed reference, despite the trunk flexion associated with the lateral reach. The presence of a counterbalancing reaction for each healthy adult is summarised in table 5.12 (Section 5.3.3).

Healthy adult no. 2: A counterbalancing reaction of the head was demonstrated. Head roll relative to the trunk was in the opposite direction to that of trunk roll (and the direction of the reach), and of a magnitude of approximately 30°. Relative to the fixed room reference, head roll was of a much smaller amplitude, being approximately 10° resulting in a position of -8° head *roll* (side-flexion in the opposite direction to the trunk and reach). Both head roll relative to the trunk and the fixed room reference were within the Polaris boundaries set for "counterbalancing with the head" as described in table 5.2. The rotations of the head relative to the trunk and the head relative to the fixed room reference for healthy adult no. 2 can be seen in figures 5.7 and 5.8 respectively.

5.3.2.d.i Patient head counterbalancing reaction

Only one patient (no. 4) demonstrated a counterbalancing of the head with respect to the trunk in the frontal plane. However, all patients extended their heads on their trunks during the reach, maintaining a position of slight head extension relative to the fixed reference, despite the trunk flexion associated with the lateral reach. The presence of a counterbalancing reaction for each subject is summarised in table 5.13 (Section 5.3.3).

Patient no. 1: No counterbalancing reaction of the head was demonstrated. Minimal head roll relative to the trunk in the direction of the reach was demonstrated (6°), resulting in a positive head roll relative to the fixed reference of a magnitude of approximately 26° accompanying the reach. Neither head roll relative to the trunk, nor head roll relative to the fixed room reference were within the Polaris boundaries set for "counterbalancing with the head" as described in table 5.2. The rotations of the head relative to the trunk and the head relative to the fixed room reference for patient no. 1 can be seen in figures 5.10 and 5.11 respectively.

5.3.2.e Movement continuity

5.3.2.e.i Healthy adult movement continuity

All six healthy adults achieved maximum trunk roll with a single continuous movement. The movement continuity of each healthy adult is summarised in table 5.12 (Section 5.3.3).

Healthy adult no. 3: The trunk roll for healthy adult no. 3 is shown in blue on the graph of the rotations of the trunk relative to the fixed room reference illustrated in figure 5.2. A typical continuous trunk roll from the start position (A-B) to the point of maximum reach (point C) was demonstrated.

5.3.2.e.ii Patient movement continuity

Four out of the six patients demonstrated a "staged" reach, achieving maximum trunk roll with at least one marked step in the graphical output of trunk roll, from the start to the peak of the reach. The remaining two patients reached with a single continuous movement. The movement continuity of each patient is summarised in table 5.13 (Section 5.3.3).

Patient no. 2: Trunk roll is shown in blue on the graph of the rotations of the trunk relative to the fixed room reference illustrated in figure 5.14. A staged reach was demonstrated with maximum trunk roll being reached in three distinct stages, as can be seen between points B and C.

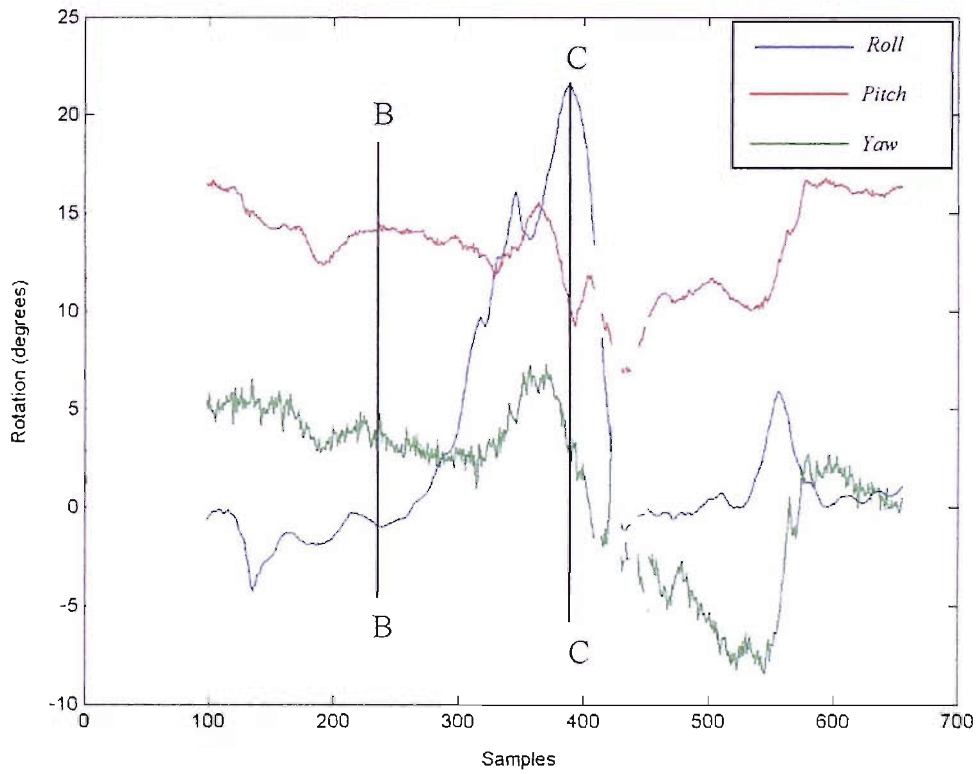

Figure 5.14 Patient no. 2 trunk relative to the fixed reference

5.3.2.f Angle of trunk *roll*

5.3.2.f.i Healthy adults Angle of trunk *roll*

The median change in trunk roll from the starting point to the maximum point of the reach was 23° with a range from 14°-38°. The relationship to the median for the angle of trunk *roll* for each healthy adult is summarised in table 5.12 (Section 5.3.3).

5.3.2.f.i Patient Angle of trunk *roll*

The median change in trunk roll from the starting point to the maximum point of the reach was 21.5 ° with a range from 8°-27°. The relationship to the median for the angle of trunk *roll* for each patient is summarised in table 5.13 (Section 5.3.3).

Using the Mann-Whitney U test to compare the degree of trunk roll demonstrated by the healthy adult and patient groups, no significant difference was found. ($Z= -.562$, $p= 0.574$).

5.3.2.g Distance reached

5.3.2.g.i Healthy adult Distance reached

The median distance reached laterally was 30 cm with a range from 23cm-37cm. The relationship to the median for distance reached for each healthy adult is summarised in table 5.12 (Section 5.3.3).

5.3.2.g.ii Patient Distance reached

The median distance reached laterally was 21.5 cm with a range from 15cm-30cm. The relationship to the median for the distance reached for each patient is summarised in table 5.12 (Section 5.3.3).

The Mann-Whitney U test was used to compare the distance reached by the healthy adult and patient groups. A significant difference was identified, with healthy adults reaching significantly further than patients. ($Z= -2.005$, $p= 0.045$).

5.3.3 Relationship between the categories of movement patterns

5.3.3.a Healthy adults

A summary of the categories of movement patterns demonstrated by the healthy adults (excluding pattern of rotations) is presented in table 5.12. One healthy adult (no. 4) demonstrated 'overshooting' on return from the reach; however, healthy adult no. 4 started the reach from a position of 'upright' head and trunk, demonstrated the use of a head counterbalancing reaction, and reached 31cm (median 30cm), with trunk roll amplitude of 26° (median 23°). Healthy adult no. 6 was the only healthy adult not to demonstrate a counterbalancing reaction with the head. As a result of not demonstrating a head counterbalancing reaction, healthy adult no. 6 also used different patterns of rotations for the head relative to trunk, and head relative to fixed reference when compared to the rest of the healthy adult sample (see tables 5.7 and 5.8 respectively). Interestingly, healthy adult no. 6 reached 33cm (above the median value), and demonstrated the largest amplitude (by far) of trunk roll (38°). The association between distance reached and amplitude of trunk roll was analysed using Spearman Rank correlation. A significant correlation was found between distance reached and trunk roll for the healthy adult sample ($r=.841$ $p=.036$).

Healthy adult no.	**Upright start position** Trunk	Head	**End position**	**Head counter-balancing**	**Movement continuity**	**Amplitude Trunk roll**	**Distance reached**
1	X	X	As start	√	√	< Median	< Median
2	√	√	As start	√	√	< Median	< Median
3	√	√	As start	√	√	> Median	> Median
4	√	√	Overshoot	√	√	> Median	> Median
5	√	X	As start	√	√	< Median	< Median
6	√	X	As start	X	√	> Median	> Median

Table 5.12 Summary of categories of movement patterns demonstrated by healthy adults

5.3.3.b Patients

A summary of the categories of movement patterns demonstrated by the patients (excluding pattern of rotations) is presented in table 5.13. Only one patient (pt no. 4) demonstrated a head counterbalancing reaction during the reach. As a consequence, patient no. 4 used different patterns of rotations for the head relative to trunk, and head relative to fixed reference when compared to the rest of the sample (see tables 5.10 and 5.11 respectively). This patient also started the reach from a non-upright head and trunk position, but did not 'overshoot', or reach in stages. Interestingly this patient reached the furthest (30cm) of the sample, and demonstrated the second lowest amplitude of trunk roll at 18°. The only patient to demonstrate an overshooting on return from the reach (pt no. 5) also reached in stages, and failed to demonstrate a head righting reaction. The association between distance reached and amplitude of trunk roll was analysed using Spearman Rank correlation. No significant correlation was found between distance reached and trunk roll for the patient sample ($r= -.086$ $p=.872$).

Patient no.	Upright start position Trunk	Head	End position	Head counter-balancing	Movement continuity	Amplitude Trunk roll	Distance reached
1	X	X	As start	X	X	> Median	> Median
2	√	X	As start	X	X	> Median	< Median
3	√	X	As start	X	X	< Median	< Median
4	X	X	As start	√	√	< Median	> Median
5	X	X	Overshoot	X	X	< Median	> Median
6	X	X	As start	X	X	> Median	< Median

Table 5.13 Summary of categories of movement patterns demonstrated by patients

5.3.4 Summary of results

Starting position

- A majority of healthy adults (five out of six) started the reach from an 'upright' trunk position. Half (three out of six) demonstrated both an 'upright' trunk and head. Failure to achieve upright was due to head and/or trunk *pitch* for all but one subject.
- None of the patients started the reach from an 'upright' position. Two patients demonstrated an upright trunk, but none an upright head. Failure to achieve upright was due to a variety of head and trunk positions including *yaw* and *roll*.

Patterns of rotation

- All healthy adults demonstrated a similar pattern of head and trunk rotations.
    - Trunk rotations were characterised by *roll* in the direction of the reach, positive *pitch* (flexion), and *yaw* (if present) away from the reach.
    - Head rotations relative to the trunk were characterised by *roll* and *yaw* away from the reach, and maintenance of head *pitch* (extension).
    - Head rotations relative to the fixed reference were characterised by minimal change in *pitch* or *roll*, and *yaw* away from the reach.
- Patients demonstrated a more variable pattern of trunk, and particularly head, rotations.
    - Trunk rotations were characterised by positive trunk *pitch* (flexion) and *roll* in the direction of the reach. The pattern of trunk *yaw* was variable between patients, and varied during the reach for three patients.
    - Head rotations were characterised by negative or no change in head *pitch* (extension), and head *yaw* away from the reach. The pattern of head *roll* was variable between patients.

   - Head rotations relative to the fixed reference were characterised by maintenance of head pitch and head roll towards the reach. Head yaw was more variable.

End position

- Only one of the six healthy adults demonstrated an 'overshooting' of the head and trunk on return from the reach.
- Only one of the six patients demonstrated an 'overshooting' of the head and trunk on return from the reach.

Presence of head counterbalancing reaction

- Five of the six healthy adults demonstrated counterbalancing with the head in the frontal plane during the reach.
- Only one of the six patients demonstrated counterbalancing with the head in the frontal plane during the reach.

Movement continuity

- All six healthy adults demonstrated a 'continuous' reach.
- Four of the six patients demonstrated a 'staged' reach.

Angle of trunk roll

- No significant difference was identified in the amplitude of trunk roll demonstrated by the patient and healthy adult groups.

Distance reached

- Healthy adults reached significantly further that the patients.

5.4 Discussion

In this work the head and trunk movement patterns demonstrated by a small sample of patients with acute stroke and healthy adults were described. The merit of describing the movement patterns of the healthy adults could be challenged. Konczak and Dichgans (1996) highlighted the conflict between the need for a standard reference against which to evaluate movement behaviour of 'atypical populations' (in this instance patients with stroke), and the use of a scientifically unproven concept of "normal" that has become a label to refer to the movements of healthy adults. Levin (1996) and Carr and Shepherd (1996) suggest the term 'effective movement' rather than 'normal' as a more appropriate term when referring to the movement strategies used by the average adult, without pathology, of a given age. Whichever term is used, the description of the movement patterns used by the healthy adult sample in this study is justified, as it provided a reference against which the movement patterns used by patients with stroke can be described.

In the following sections, the detailed descriptions of head and trunk movement patterns used by healthy adults and patients during the seated lateral reach task are discussed for each category of movement description in turn. Where possible comparisons with other studies are made, though as discussed previously these are limited.

5.4.1 Starting position

Half of the healthy adults demonstrated upright head and trunk starting positions, and a further two an upright trunk. Failure to achieve upright was accounted for by head and/or trunk *pitch* for all but one subject. Interestingly, all had achieved an upright head and trunk when requested to sit "as upright as possible" during the upright sitting task of the HAT. This provides evidence that the non-upright position was not a result of an inability to achieve upright but was likely to be due to the fact that upright was not specifically requested as the reaching start position. Two patients started the reach from a position of 'upright trunk', but none started with an 'upright head' position. Interestingly, none of the three patients (1, 4, & 5) who achieved an upright head and trunk on the upright sitting task of the HAT demonstrated an upright starting position. Consequently, neither of the two patients that started the reaching task from a position of upright trunk (nos. 2 and 3) achieved an upright trunk when assessed on the upright sitting task. As Polaris and video agreed for 100% upright trunk ratings (see Section 3A), these results appear to represents a true difference between achievement of an upright position when asked to sit "as straight as possible", and that adopted at the start of a functional task. It is likely that those patients who achieved upright for the upright sitting task did so as a result of prompting. The lack of prompt to sit 'upright' at the start of the reaching task could account for the absence of upright when compared to that achieved in the sitting task for patients 1, 4 and 5. However, starting the reach from a position of upright trunk (nos. 2 and 3) when upright trunk was not demonstrated when directly requested is more difficult to explain. This difference is perhaps a reflection of poor selective control of movement resulting in 'overuse' or 'mass movement' that may occur when the patient attempts a motor task, such as sitting as straight as possible. This thinking is supported in part by the fact that one patient was rated as not using selective movement when attempting to correct during the upright sitting task.

Another possibility accounting for the lack of upright head and trunk is whether having the reaching equipment in the visual field acted as a distraction and caused the patients to turn their heads and trunks to look at it. With the predominant picture of trunk and head *yaw* (rotation) towards the reach this is a possibility, though why the same pattern was not evident for the healthy adult sample is not clear. However, the only healthy adult to demonstrate anything other than pitch accounting for the non-upright head did also show head *yaw* towards the reach. A further possibility is that the trunk and head *yaw* towards the reach seen in patients reflected a relationship between position and side of hemiplegia, as all were rotated away from their affected side. Further insight would have been gained if the subjects had been requested to sit as straight as possible at the start of the reaching task.

5.4.2 Rotations

Variations in the pattern of head and trunk rotations were predominantly accounted for by head *roll* (side flexion). A distinct pattern of head *roll* was associated with demonstration of a head counterbalancing reaction, meaning that five out of the six healthy adults demonstrated a similar pattern of head and trunk rotations. With only one of the six patients demonstrating a counterbalancing reaction of the head, this group demonstrated more varied patterns. Figures 3A.5 and 3A.8 (Section 3B) illustrate the presence and absence of a head counterbalancing reaction respectively. The typical pattern demonstrated by the subjects demonstrating a head counterbalancing reaction was characterised by trunk flexion, trunk side flexion in the direction of the reach, trunk rotation away from the reach (if present), head side flexion and rotation away from the reach, and extension. The resulting pattern of rotations of the head relative to the fixed room reference was that of minimal rotation in any plane, maintaining a relatively neutral and stable head position with respect to the environment.

Four patients demonstrated fluctuation in direction of movement during the reach. Three patients demonstrated a change in direction of trunk (*yaw*) rotation, and one demonstrated fluctuating head (*yaw*). One possible explanation is that this was a result of a delayed balance response. This is supported by the fact that the initial direction was away from the predominant pattern used by both samples, and the final direction change was towards the direction used by the majority, and away from the reach. One healthy adult demonstrated fluctuating head *roll,* though this was of smaller magnitude and *roll* fluctuated around the neutral position.

Interestingly, though one healthy adult and five patients failed to demonstrate a head counterbalancing reaction in the frontal plane, all subjects demonstrated a head counterbalancing reaction in the sagittal plane, i.e. despite the large degree of trunk flexion associated with the lateral reach, the head position relative to the fixed room reference was maintained in a position of slight extension. This finding supports the theory that head counterbalancing is easier in the sagittal plane compared to the frontal plane. When looking at the two reaching tasks of the HAT it was evident that more patients demonstrated head counterbalancing on the forward reach as opposed to the lateral reach. The results also highlight another reason why the lateral reach may be more challenging than the forward reach, as a counterbalancing reaction in both the frontal and sagittal planes is suggestive of the most effective strategy.

5.4.3 End position

During the video analysis of head activity used by patients during the lateral reach for the HAT (as described in Section 4B) the researcher had observed a tendency for some patients to return to a point beyond their starting position, and then correct for this apparent 'overshooting'. The three dimensional motion data of the end position was therefore analysed. Only one patient demonstrated 'overshooting' in this sample, and, perhaps more surprisingly, one healthy adult also demonstrated 'overshooting'. No other reports of 'overshooting' or similar features were found in the literature describing movement strategies of patients with stroke in sitting. The researcher did not note 'overshooting' to be apparent during the forward reaching task of the HAT, and it is perhaps a phenomenon only relevant to certain tasks, particularly those challenging lateral postural stability.

5.4.4 Head counterbalancing reaction

A counterbalancing reaction of the head was demonstrated by five of the six healthy adults, but only one of the six patients. This lack of head righting was expected in the patient sample and has been previously reported as a consequence of stroke (Bobath, 1990; Davies, 1990; Edwards, 1996; Campbell et al., 2001). Davies (1990) suggests patients have difficulty using head counterbalancing reactions due to the inability of the weakened abdominal muscles to hold the ribs down. As a result, the trunk cannot shorten on the opposite side as the lateral flexion involves the abdominals. In addition the hemiplegic leg cannot abduct and extend to act as a counter-weight as the pelvis is not able to provide a stable anchorage for the necessary muscles without the abdominals acting as fixators. The retraining of head and trunk righting reactions are frequently used as treatment in the early stages of balance rehabilitation following stroke. In a tool recently developed to measure motor impairment of the trunk following stroke (Verheyden et al., 2004), appropriate shortening and lengthening of both sides of the trunk were seen to be key markers of dynamic sitting balance and quality of trunk movement.

5.4.5 Movement continuity

Four of the six patients demonstrated a staged reach. In comparison, all healthy adults demonstrated a single continuous trunk *roll* from the start of the reach to its peak.

Segmented, multi-peaked reaching trajectories as a feature of seated reaching patterns following stroke have been previously described (Cristea and Levin, 2000; Theilman et al., 2004) (see Section 5.1.1. for more details). The authors attribute the segmented movement to a lack of inter-joint coordination. With only head and trunk marker configurations used in this study, it is not possible to comment further on the trunk and upper limb inter-joint coordination demonstrated during this seated lateral reaching task. It is also possible that the staged reach was a result of hesitancy and lack of confidence by the patient, during what was a relatively novel task. This is perhaps particularly relevant in this task as the presence of a visual fixation meant that subjects were required to reach without looking where they were going. Patients, especially those with sensory impairment, may have found the task particularly daunting. It would have been interesting to see whether this movement pattern changed, if the reach had been repeated a number of times, and the task had become more familiar.

5.4.6 Angle of trunk roll

No significant difference was found between the amplitude of trunk *roll* demonstrated by the patient and healthy adult sample. Because of the small numbers in the samples the relationship between the presence of a head righting reaction and the amplitude of trunk *roll* could not be explored. The lack of a significant difference between the amplitude of trunk *roll* demonstrated by healthy adults and patient, and the significant correlation between distance reached and trunk *roll* for the healthy adult sample, but not the patient sample, suggests that the relationship between trunk *roll* and distance reached is not simple. It is possible that the upper and lower trunk contribution to trunk *roll* varied between the healthy adult and patient samples, but unfortunately, only one marker configuration was placed on the trunk and none were placed on the pelvis, meaning segmental trunk and pelvis movement data are not available. Again further research is required to investigate the relationship between movement strategy used and distance reached.

5.4.7 Distance reached

Unfortunately the samples in this study were too small to answer the question as to whether the quality of the reaching strategy used, in terms of the presence of a head righting reaction, was associated with distance reached. Interestingly, the only patient to demonstrate a head counterbalancing reaction demonstrated the greatest distance reached by the patient sample. However, the only healthy adult not to demonstrate a head counterbalancing reaction also demonstrated a relatively large reach.

A particularly interesting result of this study was that the patients demonstrated similar amplitudes of trunk roll but a significantly lower distance reached when compared with the healthy adults. One possibility is that although patients had similar amplitude of trunk roll, a lack of lateral pelvic tilt, head counterbalancing reaction, and opposite trunk lengthening and shortening meant that they could not control their centre of mass within their base of support, and as a result reached a shorter distance. It is possible that greater stability and trunk lengthening allows a greater distance to be reached through the exploitation of larger degrees of freedom of the upper limb and shoulder girdle. While the results from this study support the lack of head counterbalancing reaction, no data were collected for pelvic or segmental trunk rotation, or centre of pressure excursion. During a similar lateral reaching task in sitting, Campbell et al. (2001) described a reduced lateral pelvic tilt in patients following stroke, and suggested that pelvic fixation, limiting lower trunk mobility, may act to restrict the movement of the centre of mass over the base of support.

5.4.8 Study limitations

5.4.8.a Sample

A recurrent feature of the work presented in this thesis is the limitation imposed by the small size of both the healthy adult and patient samples. With respect to the healthy adult sample, a further limitation is imposed in this study by the fact that the sample was not age-matched. For the patient sample, the small size was further compounded by the limited variability; all six patients had right hemispheric strokes, and all were assessed in the third week following stroke.

5.4.8.b Procedure

Limitations to this study were introduced as a result of the data being collected primarily for establishing the external criterion validity of the HAT, and not with the single aim of providing a detailed description of head and trunk movement patterns during the lateral reach task. The first limitation was that the subject's height and/or arm length as not recorded, meaning that distance reached cannot be described adjusted for height (as suggested by Stack (2003); see Section 4.1.6.e.). As the lateral reach task formed part of a larger task only a single reach was performed. Clearly, repeated reaching would have provided a greater depth of data, particularly related to change in movement patterns with task practice. Again, as a result of the task being part of the HAT, a visual fix was used (see Section 3.3.1.b.v). Repeated reaching with and without the visual fix would have allowed the effect of visual fixation on the pattern of head and trunk movement used and distance reached to be described. Repeated reaching would also have allowed the movement patterns to be described when subjects reached with their non-dominant, or affected arm. In this way differences in strategies used to each side could have been described.

5.4.8.c Equipment

Once again using Polaris in the analysis of head activity introduced several limitations to the work presented in this study.

5.4.8.c.i Combined movement accuracy

As Polaris calculates angle change between marker configuration position using a set order of rotations, and these rotations are about the axis of the marker configuration, which changes throughout the movement process, caution is required in interpreting the Polaris results in any detail. For this reason only patterns of rotations were described for the head and trunk, rather than amplitude of rotations in each of the three planes. However, amplitude of trunk side flexion (*roll*) was reported in degrees, and caution needs to be taken in interpreting the results. Trunk roll dominated trunk movement and the relatively large amplitude recorded for all subjects meant that any measurement error was likely to have been relatively small.

5.4.8.c.ii Sampling rate

Limitations were introduced by the unreliability of Polaris sampling rate (see Section 3.1.2.b for further details). As a result, rating time-dependent features of head activity was not possible, and speed of reach could not be analysed. For this reason it is not possible to confirm (as seems to be suggested by the data) the presence of a difference between the speed of reach and the speed of return demonstrated by healthy adults and patients. Looking at the graphs, the healthy adult reach appears to be characterised by a symmetrical 'reach' and 'return' phase, with a plateau at the point of maximum distance reached. Thus, healthy adults appear to demonstrate a holding of the reach at the most challenging point of the task (the point of maximum reach). In contrast, the patients' data suggest an asymmetrical reaching pattern, with a less steep reach phase, followed immediately by a steeper return. Several previous studies have reported slower movements demonstrated by patients compared to healthy adults during seated reaching (Campbell, 1998; Cristea and Levin, 2000; Theilman et al., 2004) and during seated trunk flexion (Messier, 2003). Further studies using more reliable three-dimensional motion analysis equipment are required to support the suggestion made from this data that following stroke lateral reach is characterised by its slow speed and immediate return.

5.4.8.c.iii Numbers of markers

Only three marker configurations were used in this study. Although this enabled rotations of the trunk relative to the fixed reference, the head relative to the trunk, and as a result head rotations relative to the fixed reference in terms of head movement alone and head movement as a result of trunk movement, many questions regarding movement patterns remain unanswered. Use of markers on different segments of the trunk (i.e. upper and lower), shoulder girdle and upper limb, pelvis and the lower limb would have allowed the relative contributions of these body segments to the movement patterns to be analysed.

5.4.8.c.iv Force data

Unfortunately no force data were collected in this work, limiting the interpretations of the motion analysis that can be made. In particular, data for the patterns of weight bearing through the thighs, buttocks, and the feet (centre of pressure (COP) excursion) would have enabled any relationship between head and trunk movement patterns, weight transfer, and distance reached to be described. Messier et al., (2003) found reduced COP excursion during seated trunk flexion in a small sample of patients with sub-acute and chronic stroke, when compared to healthy adults. The authors suggest reduced anterior pelvic tilt may have accounted for the reduction in COP excursion, but unfortunately no data were collected for segmental trunk or pelvic movement. Again this highlights the need for further work using increased numbers of markers, ***and*** collection of force data.

5.4.8.d One-off Measurement

Acknowledged strengths of this study were the assessment of patients just three weeks following stroke, and the fact that all patients were at the same time point in the recovery process. However, a study limitation was introduced in that Polaris data were not collected on all three patient assessments, meaning that in-depth descriptions of changes in head and trunk movement patterns in the early stages of recovery following stroke have not been possible in this work.

5.4.8.e Suggestions to overcome limitations in future work

It is evident from the limitations encountered using Polaris that in any future work the three-dimensional motion analysis system used needs to have:

- A relatively large recording volume, reducing the risk of missing end-of-range data.
- Greater accuracy in reporting combined rotations.
- A reliable sampling rate, allowing accurate timing of events to be obtained.
- The ability to track multiple markers without altering the sampling rate.

It is suggested that future work looking at head and trunk activity following acute stroke should be carried out with repeated measures on larger samples, in both the acute clinical setting and the laboratory. In the acute clinical setting the advantages offered by the very acute sample cannot be overlooked, and three-dimensional motion data (using portable systems) can be collected in conjunction with clinical data, but the data are subject to the limitations of the portable systems. It is therefore suggested that laboratory-based research should also be undertaken. In the laboratory the use of additional markers, a Balance Performance Monitor, and a force plate under the subject's feet would be possible. In addition, a greater choice of three-dimensional motion analysis equipment is available for use in the laboratory.

5.9 Summary

It is evident from the results of the three-dimensional motion data that different head and trunk movement patterns were demonstrated by the patient sample when compared to those used by a sample of healthy adults. However, what remains unknown is whether the motor deficit seen is a direct result of the stroke, or whether it is an adaptive movement strategy deployed by the patient. Latash and Anson (1996) suggested that movement strategies different from those typically observed in healthy people should be considered as adaptive and should not be corrected. They suggest that only the primary causes of the movement deficits should be treated. Others, however, argue that this is too simple an approach and that the distinction between the primary causes of motor deficits and adaptive changes in motor performance is not always possible (e.g. Levin, 1996; Konczak and Dichgans, 1996). Following stroke the picture is further complicated as there is a need to take the role of recovery into account. Whether the head and trunk movement patterns demonstrated in this study were beneficial or detrimental to the patient has not been answered. To answer this question any link between head activity (demonstrated in the acute stages following stroke) and functional outcome needs to be established, and any long-term consequences of abnormal head activity need to be identified. What can be argued however, is that the judgment of whether the altered movement patterns were appropriate or not is more complex than suggested by Latash and Anson (1996).

5.10 Conclusion

The results from this study support the original study hypothesis that abnormal head activity is a feature of stroke. The detail provided by the three-dimensional motion analysis data furthers the description of head activity, gained through the use of the HAT, of both healthy adults and patients with stroke. The detailed description provides insight into the possible mechanisms underlying head activity, and highlights potential intervention strategies for the treatment of abnormal head activity following stroke.

Chapter 6

Discussion

6.1 Introduction

In this final chapter, the work undertaken in this thesis to further the understanding of head activity following stroke is discussed. In Section 6.2 the hypotheses set out at the beginning of the project are revisited. In the subsequent sections (6.3-6.6) the contributions made by the development of the HAT, the use of the HAT to describe the head activity used by a small sample of healthy adults and patients following acute stroke, interviewing patients about their perception of head activity, and detailed three-dimensional motion analysis of head activity during a lateral reach, are each discussed in turn. A new theory of the recovery of head activity following acute stroke is proposed in Section 6.7. The limitations of the work undertaken, and their impact on the inferences that can be made, are considered in Section 6.8. The clinical implications of this work, in relation to both the therapists' and patients' perspectives, are discussed in Section 6.9. Finally, in Section 6.10 recommendations for future research are proposed.

6.2 Original study hypotheses

The importance of rehabilitation of postural control following stroke is undisputed. Evidence suggests a positive correlation between recovery of early postural control (sitting balance and trunk control) and good rehabilitation outcome (Sandin and Smith, 1990; Morgan, 1994; Smith and Baer, 1999; Ching-Lin et al., 2002). It is known that head activity plays a key role in normal postural control, and abnormalities of head activity following stroke have been described for years by the physiotherapy pioneers (e.g. Bobath, 1990; Davies, 1990). More recently Tyson and De Souza (2003) reported abnormalities of head activity as factors identified by practising clinicians as limiting a patient's ability to perform a function. However, to date no research has been undertaken to investigate how abnormalities of head activity following stroke present during everyday tasks. In addition, how head activity recovers following acute stroke, and the relationship between the level and recovery of head activity, and postural control and functional outcome remain unknown.

The primary hypothesis set out at the start of the project stated that impaired head activity was a frequent early consequence of stroke, and that patients would demonstrate abnormalities of head activity during simple seated functional tasks. It seemed reasonable that the level of head activity demonstrated by patients would be associated with type of stroke, motor and balance impairment, and functional ability. I reasoned that those with poor head activity in the first week following stroke would have lower functional outcome at six weeks compared with those with good initial head activity.

The work undertaken attempted to support or refute the study hypotheses by meeting the following study aims:

- **To develop a valid and reliable clinical tool to assess head activity following acute stroke**
- **To describe the head activity used by a sample of healthy adults and a sample of patients with first-ever acute stroke**
    - To describe any association between level of head activity and classification of stroke
    - To identify correlates of abnormal head activity
    - To describe the recovery of head activity in the first six weeks following stroke
    - To identify any association between level of head activity and functional outcome
- **To gain an understanding into the patient's perspective of any difficulty with head activity experienced following stroke**
- **To describe in detail the three-dimensional patterns of head and trunk movement used during a seated lateral reach.**

6.3 The HAT

The first contribution of this work has been the design and development of a method of describing the head activity of patients with acute stroke – The HAT.

The HAT is the first known clinical method of describing head activity during simple functional tasks. The hypothesis that underpinned the development of the HAT states that the tool provides a comprehensive record of head activity, sensitive to change over time. In designing the HAT several key methodological decisions were made, and their significance is discussed in the following sections.

The first issue encountered in the tool development process was justifying the need for a new assessment tool. The question must be asked, why, if a good criterion measure already exists, is a new tool being developed? Streiner and Norman (1995) suggest four possible reasons: that the existing measure is too expensive, more invasive, dangerous, or more time-consuming. In the case of Polaris it is certainly too expensive for routine clinical use, costing approximately £15,000. Polaris can also be considered invasive, as subjects have to wear head and chest 'marker configurations'. In contrast, when using the HAT to assess head activity, most rehabilitation departments already have a video camera, no equipment needs to be worn, and set up time is minimal. Even with recent technological advances (e.g. the development of portable CODA) the cost of such equipment in terms of the financial cost and the patient's and therapist's time make it prohibitive for routine clinical use for the foreseeable future. With no clinical tool reported in the literature, the need was established.

It was the primary development criterion that the assessment tool would be suitable for use in the acute clinical setting. Theoretically, it would have been possible to develop a laboratory-based method of assessment, for later development into a clinical tool. However, huge problems in recruiting patients to laboratory-based studies in the very acute stages of recovery exist, and can result in non-representative, more able samples, in whom abnormalities of head activity may be infrequently seen. The long-term aim is that the HAT will be live-rated. Despite this, it was felt essential to use a method of recording the head activity demonstrated at this early stage in the development process. The use of video recording meant that the head activity demonstrated could be repeatedly analysed and discussed with clinical expert groups, that reliability and validity could be thoroughly tested, and the raw data explored. The difficulties encountered with immediate live rating of a tool under development, especially with respect to establishing reliability and validity, were evident in the studies by Carr et al. (1995; 1999) and Nieuwboeur (1995). The lack of data available to explore poor results or confirm good results severely hampered the development of the tools reported.

A key decision taken early in the development of the HAT was the level at which to measure head activity. The World Health Organisation (WHO) defines four levels of illness: pathology, impairment, activity, and participation (ICIDH-2, 2002). The HAT measures head activity at the activity level, describing the observed behaviour of an individual interacting with the environment. Altorfer (2000) states that description is a necessary first step to developing an understanding of a phenomenon. The decision to measure at the activity level can be justified by the fact that it meets this need to describe head activity at the beginning of an investigation into head activity and its recovery following stroke. Measuring head activity at the activity level is, however, only a starting point. To fully understand the mechanisms underlying head activity, and the impact abnormalities of head activity have on the patient's daily life, head activity also needs to be assessed at the impairment and participation level respectively.

In figure 6.1 a model of the multi-level assessment of head activity is presented. In the centre of the figure is a time-line from onset of stroke to the regaining of maximum functional independence. Below the line the gaps in knowledge identified at the beginning of the thesis, at the impairment, activity, and functional levels in relation to head activity following stroke are presented. In the top half of the figure the contributions made by the work undertaken in this thesis are detailed. Specifically, where the HAT fits with respect to the levels of measurement and the contributions made through its use are illustrated. It is evident from figure 6.1 that all the contributions made by this work have been at the activity level. The gaps remaining in our understanding of head activity and its recovery following stroke, and their implications in overcoming the impairments to promote optimal functional recovery are highlighted.

Understanding the mechanisms underpinning head activity is required if effective treatment strategies are to be developed. To date it is not known whether the abnormalities of head activity are as a direct result of the stroke, for example due to a deficit in vestibular function or sensori-motor integration, or whether they are secondary consequences of the stroke, and are compensation strategies deployed by the patient as a result of reduced postural control. Clearly the answers to these questions are required if the development of effective treatment approaches for patients with abnormal head activity and postural control deficits following stroke is to be realised. Demonstrating an association between abnormal head activity and reduced functional independence is essential if interventions are to be justified, as it is the level of participation that really matters to the patient, and is the primary goal of rehabilitation. Assessment of head activity at the impairment level and assessing the influence of abnormal head activity on the patient's level of participation were not within the scope of this work, but recommendations for future research (see Section 6.10) have been proposed.

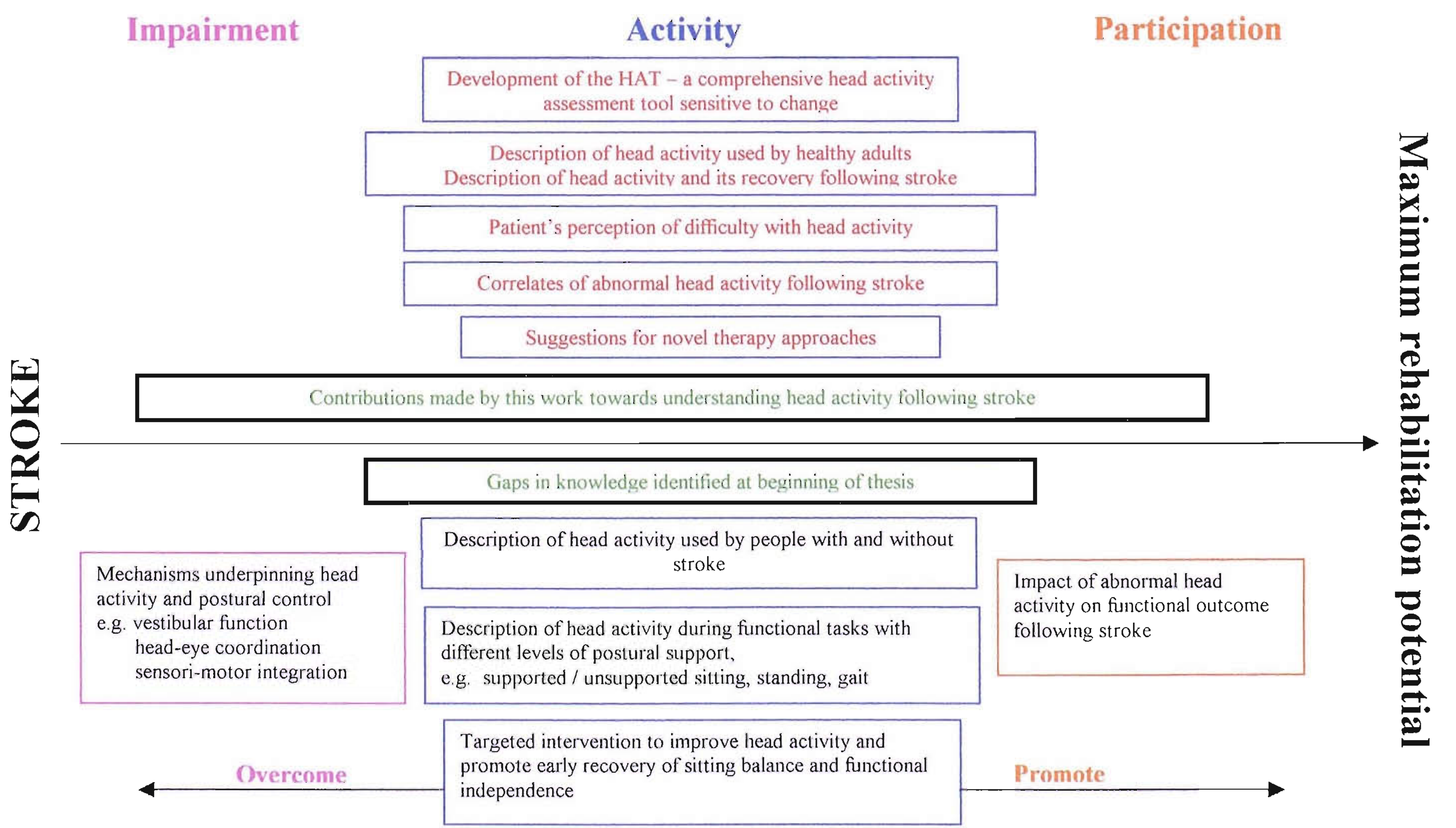

Figure 6.1 Contributions made to the knowledge of head activity following stroke

In deciding the components of the HAT, the decision was taken to use functional tasks. The five tasks developed in this work that make up the HAT are upright sitting, visual search, communication, eating, and reaching. The tasks present different challenges in terms of the level of physical, environmental, and social and cognitive demands they place on the subject. With the HAT being purposely designed for use with people following acute stroke, the tasks were chosen specifically to highlight abnormalities particular to this population. The different tasks chosen reflect the different roles of head activity, and include bilateral tasks with the potential to describe differences in movement patterns used between sides, specifically in the visual search and communication tasks. The HAT captures the role of the head in: i) sensory interaction with the environment, in visually locating targets (as assessed by the visual search task), and in communication (as assessed by the communication task); ii) coordinated movement with the trunk and upper limb (as assessed by the eating task); iii) balance control (dynamic postural stability), as assessed by the reaching task; and iv) achieving and maintaining a static posture (static postural stability) as assessed by the upright sitting task. A comprehensive selection of tasks was chosen at this early stage in the investigation of head activity, as it was not known in which roles of head activity abnormalities would be demonstrated. The use of functional tasks also lends the HAT for use in the identification of task-specific treatment approaches. The latter is supported by recent evidence suggesting that task-specific treatment approaches, as opposed to impairment-orientated treatments, are more effective in rehabilitation of function following stroke (Langhorne et al., 1996; Kwakkel et al., 1999; Wu et al., 2000) (see Section 6.8.2.a). A frequent criticism of research looking at the efficacy of interventions in stroke rehabilitation has been the use of inappropriate measurement tools. Any assessment tool developed would therefore need to reflect the aims of any interventions developed in the management of head activity following stroke. It is interesting that in a recently published tool to measure 'motor impairment of the trunk following stroke', the Trunk Impairment Scale (Verheyden et al., 2004), trunk movement was assessed from an impairment approach rather than a task-orientated approach, despite assessment being at the activity level. For example, to assess whether or not patients demonstrated opposite trunk lengthening and shortening the assessor asks the subject to lift the pelvis on one side. Such an assessment method fails to answer the question as to whether the patient would show opposite trunk lengthening and shortening during functional tasks.

The HAT demonstrated external validity against a criterion measure and acceptable levels of reliability. Results from its early use suggest that the HAT has the potential to be modified to improve its clinical application. In particular, the visual search task currently relies on special equipment that could be modified to reduce the set up time, and increase the portability of the assessment tool. A further long-term aim would be for the HAT to be live-rated. Importantly, this would reduce the time required to analyse the results making it more applicable for routine clinical practice. It is, however, recognised, that at this very early stage in the tool development process, repeated use of the tool in its current format is required to confirm or challenge the suitability of any proposed change. Any future modifications to the HAT would require research to verify the modified version retained both validity and reliability.

6.4 Description of head activity following stroke

The second contribution of this work has been the use of the HAT to describe the head activity of a sample of healthy adults, and head activity and its recovery in a sample of patients in the first six weeks following acute stroke.

The small samples recruited to both the healthy adult and patient studies (Sections 4A and 4B respectively) restrict the conclusions that can be drawn from the studies in which the HAT was used for the first time. However, despite these limitations, the work makes an important contribution, describing the head activity used by healthy adults and patients with stroke during seated functional tasks. A significant aspect of this work was that head activity was described in the patient sample in the first week following stroke. It is at this very acute stage of recovery that abnormalities are likely to be most apparent, and any intervention targeted to improve head activity would be most effective.

6.4.1 Description of head activity

Head activity was described in terms of total HAT score, and a description of the movement patterns demonstrated during each of the five tasks. Describing head activity in these ways met three purposes. Firstly, the total HAT score enabled head activity of the sample as a whole to be described. Total scores also allowed the level of head activity to be defined allowing comparisons to be made between those with different levels of head activity. Finally, descriptions of the patterns of head and trunk movement for each of the five tasks enabled a more detailed picture of head activity to be established. It must be stressed that the HAT results purely provide a description of head activity, and the mechanisms underlying the abnormalities of head activity seen cannot be attributed.

6.4.1.a Head activity used by healthy adults

A sample of healthy adults was used not to define 'normality' but to serve as a background against which changes in head activity following stroke could be highlighted. The results from the healthy adult study (Section 4A) established a 'typical' pattern of head activity demonstrated by healthy adults (as rated by the HAT), which was characterised by:

- Gaining a maximum HAT score of 10.
- Achieving and maintaining an upright head and trunk position in the sitting position.
- Visually searching in both directions, and if using the trunk to search, moving the head and trunk freely, demonstrating an ability to dissociate head and trunk movement.
- Orientating the head towards the interviewer and using the head for gestures
- Using the 'meet in the middle' feeding action, demonstrating coordinated movement of the upper limb, head, and trunk.
- Demonstrating a head righting reaction on the forward and lateral seated reaches, again demonstrating an ability to dissociate head and trunk movement.

Whilst the HAT was not developed to rate the head activity of those without stroke, the gross description of head activity provided highlighted the lack of variation in head activity demonstrated by the sample. When the HAT was repeated on two further occasions no change in score was seen for any participant. The results of this work confirm a 'typical' and consistent pattern of head activity used by healthy adults. Establishing 'typical' head activity contributes towards developing an understanding of the mechanisms underlying abnormal head activity following stroke, and possible intervention strategies.

6.4.1.b Head activity used by patients following acute stroke

The results from the first assessment of the patient study (Section 4B) describe the head activity used during seated functional tasks, demonstrated in the first week following stroke. The results support the primary hypothesis of the thesis that abnormal head activity is a frequent early feature of stroke, and that patients demonstrate abnormalities of head activity during simple seated functional tasks. Total HAT scores ranged from the minimum (zero) to the maximum (ten) score, illustrating the wide range in head activity demonstrated by the small sample of patients that characterised the results. Descriptions of the pattern of head and trunk movement for each of the five tasks identified key features of the head activity demonstrated by patients:

- More than half (8/13) of the patients rated on individual tasks failed to achieve an upright head and trunk position on the upright sitting task.
- Just under half (5/12) failed to demonstrate the use of 'selective movement' when correcting their sitting position
- An apparent inability to dissociate head and trunk activity was demonstrated by patients on both the visual search and the reaching task.
- One patient demonstrated differences in the head activity used to each side during the visual search and communication tasks.
- Two patients demonstrated a reluctance to move their trunks on both the eating and visual search tasks.
- Half (7/13) of the patients failed to demonstrate a head righting reaction during the forward reach,
- Only two patients demonstrated head righting on the lateral reaching task.

The apparent inability to dissociate head and trunk movements demonstrated by some patients during the reaching and the visual search tasks, and in the lack of selective movement on the upright sitting task, supports the suggestion made by Campbell et al. (2001) that patients have difficulty dissociating segmental movements of the head and trunk. The finding that two patients showed a reluctance to move their trunks during the visual search task (tool item: trunk movement) and during the eating task further supports the finding that patients demonstrate difficulty dissociating head and trunk movement. The findings from the tasks suggest that different movement patterns may be deployed depending on the task being carried out. It is possible that fixing the head on a moving trunk, fixing the trunk and moving the head on a stationary trunk, or moving neither, are all movement patterns demonstrated as a result of difficulty dissociating head and trunk movement, but that the exact movement pattern depends on the goal of the task. For example, during the eating task it is possible to achieve the task goal (spoon to mouth) without moving the head and trunk. In contrast, during the visual search task the head has to move to achieve the goal, and during the reaching task the trunk has to move in order for the patient to reach. Taking this thinking further, it is possible that a hierarchy exists within the patterns (goal achievement allowing). Looking at the results for the only task that enabled the goal to be achieved by more than one of these movement patterns (the visual search task) reveals that two patients demonstrated head movement alone, and three demonstrated head fixed on trunk movement. With such small numbers it is not possible to further explore a hierarchical pattern, but it is interesting to note that the lowest two HAT scores at assessment one were scored by the patients demonstrating head movement alone on the visual search task. The findings suggest that different patterns of head and trunk movement may present in everyday tasks as a result of difficulty dissociating head and trunk movement, and not just a head fixed on trunk stabilising strategy. To further explore the relationship between the different patterns demonstrated, studies using the HAT with larger samples and investigation into the mechanisms underpinning head and trunk movement patterns are required.

Unfortunately only one patient with neglect was assessed using the HAT for the individual tasks. The results from this subject do, however, describe an asymmetry in the movement patterns demonstrated to each side for the visual search and communication task. Again, use of the HAT with increased numbers of patients is required to confirm whether this is a typical pattern demonstrated by all patients with neglect, and to describe any change in head activity that occurs with the recovery or persistence of neglect. The results from the patient sample suggest that the tool items 'search strategy' for the visual search task, and 'orientation of the head' and 'gesture use' for the communication task, rate an aspect of head activity uniquely related to the presence of unilateral neglect, and suggest an underlying mechanism different to that of achieving an upright head and trunk position and the ability to dissociate head and trunk movement. However, whether achieving an upright head and trunk position and dissociating head and trunk movements are aspects of head activity with similar underlying mechanisms was not addressed in this thesis. The results from the patient study highlight the as yet unanswered question raised in the literature review (Chapter 1), as to whether postural disorders following stroke are caused by a misrepresentation of verticality, an impaired postural stabilisation, or a combination of the two.

6.4.2 Head activity and classification of stroke

Those with PICH and TACI had significantly lower HAT scores in week one than those with LACI, PACI, or POCI. A similar pattern has been demonstrated in achievement of mobility milestones with those with PICH and TACI taking longer on average to achieve independent sitting balance, standing, stepping and walking (Smith and Baer, 1999). As the multiple tasks that make up the HAT challenge different roles of head activity, which are likely to be controlled by different underlying mechanisms, it was expected that lower HAT scores (more abnormal head activity) would be associated with a more severe stroke and damage to a larger area of the brain (TACI, PICH). The results support the hypothesis set out at the beginning of the thesis that level of head activity is associated with classification of stroke.

As the results from this study suggest that those with TACI, and PICH have lower HAT scores at week one, and the achievement of mobility milestones reported by Smith and Baer (1999) suggest those with TACI and PICH take longer to achieve independent sitting, the question arises as to whether a critical level of head activity is required to achieve independent sitting balance. This question has not been addressed by the work in this thesis due to the small sample size. Further studies, with a greater number of patients followed over time, would be required to investigate the existence of a ‘critical level’ of head and trunk activity. One problem that would be encountered in attempting to answer this question is the different definitions of independent sitting balance that exist (see Section 1.3.1). For example, whether the assessment of independent sitting has a quality and/or dynamic element is likely to affect whether head activity is critical, and if so what the critical level is. This again highlights the limitation of the lack of a universally accepted definition of independent sitting balance.

With an association identified between classification of stroke and HAT score it seems feasible that stroke classification could be used to target the patients most appropriate for any intervention aimed at improving recovery of head activity following stroke. However, classification on its own is likely not to have sufficient specificity or sensitivity in identifying the patients best suited for an intervention. The individual patient profiles presented in Section 4B.4 support this thinking. For example, patient no. 2, who suffered a LACI, had an initial low HAT score of four at week one, which remained unchanged at week three, and increased only to five at week six. Selecting patients by classification only would have meant this patient would not have been targeted for treatment. Further studies with larger numbers of patients would allow multiple regression analysis to be undertaken in an attempt to identify predictors of poor recovery of head and trunk activity following stroke. The results from this study suggest that initial HAT score is likely to contribute to the identification of patients most likely to benefit from a specific intervention aimed at improving recovery of head and trunk activity following stroke.

6.4.3 Correlates of abnormal head activity

Head activity (HAT score) in week one was significantly correlated with ADL ability (Barthel Index), motor impairment (Rivermead Motor Assessment), sensory impairment (Nottingham sensory Assessment), and balance (Berg Balance Scale). It could be argued that the wide diversity of correlates identified supports the construct that the different tasks that make up the HAT challenge different roles of head activity. The results are also in line with the thinking that abnormalities of postural control following stroke (including head activity) are underpinned by multifaceted mechanisms involving motor, sensory and cognitive impairments, and their integration, as proposed by Lamontagne et al. (2003).

6.4.4 Changes in head activity

The results from the patient study suggest that the HAT is sensitive to changes in head activity in the first six weeks following stroke. HAT score changed significantly between weeks one and six, but even with the small study sample different patterns within this trend were evident. Individual patient profiles were used to illustrate this variability. The patient profiles were a means by which more in-depth analysis of change in head activity could be undertaken. Individual patient scores suggests it may be possible, and of benefit, to categorise patients in accordance with their initial level of head activity and/or early rate of change in HAT score. Sandin and Smith (1990) suggest that both initial level and early change in level of sitting balance are predictors of outcome. In line with this suggestion and the patient profile results, it is perhaps those with low initial HAT score and those with low, or no, early change in HAT score who would benefit most from an intervention targeting recovery of head activity. Again further research is required to support this.

The finding that less than half the sample sat with an upright head and trunk at the end of week three, yet all could sit independently (as rated without a quality of position of dynamic component), further supports the need for a universally accepted definition of what constitutes independent sitting. The results also suggest that a level of function (reflected in Barthel and Rivermead Motor Assessment scores) is possible without achievement of sitting with an aligned head and trunk. This could be seen to challenge the belief of the physiotherapy pioneers that the ability to achieve a sitting position with an aligned head and trunk is a prerequisite to 'efficient' functional movement (Brunnstrom, 1970; Knott and Voss, 1968; Carr and Shepherd, 1987; Bobath, 1990). However, both the effect of HAT scores on functional outcome and the definition of what constitutes "efficient" functional movement require further investigation.

The HAT results from the prospective study highlighted patterns of recovery of head activity, within which some evidence of a hierarchical recovery was found. Within the small sample there was a trend towards achievement of head and trunk alignment and dissociation of head and trunk movement during the less balance demanding tasks of visual searching and eating, prior to demonstrating head counterbalancing on the forwards, and particularly the lateral, reach. Further, no change in scores for the reaching task was demonstrated for any patient between assessments two and three. These results suggest a plateauing of HAT scores at eight or nine, with lack of achievement of head counterbalancing on the lateral reach and sometimes the forwards reach as well. This levelling off of improvement in HAT scores could be interpreted as indicative of a missed opportunity to optimise the recovery of head and trunk activity following stroke through targeted intervention.

The changes in head activity seen in the prospective study were consistently maintained. The lack of fluctuations in the results could be seen to support the thinking that the changes in head activity seen represented more 'efficient' movement patterns, and therefore once achieved continue to be used, despite the remaining impairments following stroke. This raises the question as to the possibility of the existence not just of a critical level of head and trunk activity required to achieve independent sitting balance, but also of a critical level of recovery following stroke above which it is 'efficient' to use more 'typical' patterns of head activity. In contrast those with poorer recovery may 'need' abnormal head activity (such as lack of head and trunk dissociation) just to remain upright. The suggestions emphasise the need to increase our understanding of the mechanisms underpinning abnormalities of head activity following stroke in order to unravel these related issues, and identify the most effective intervention strategies for different patient groups.

6.4.5 HAT score and functional outcome

Total HAT scores allowed the level of head activity to be defined for the small sample of patients followed over the six-week assessment period. Initial HAT scores were defined as low (less than median score) or high (see Section 4B.3.5.f). No significant difference was found between those with high HAT scores and those with low scores at week one, and functional outcome or level of balance at week six. The hypothesis that those with low HAT scores in week one would have lower functional and balance scores at week six than those with high initial HAT scores was therefore not supported by this work, but it was not refuted. The sample size is likely to have made a major contribution to this finding. Once again, a larger study is required to further test this hypothesis.

Further exploration of the results suggested that not only was there no significant difference in the functional outcome between those with initial low, and those with high HAT scores, but that not all patients with good functional levels (as assessed by the Barthel Index) had good HAT scores. The individual profile of patient no. 2 illustrates this lack of correlation, with a Barthel Index score of 18 at week six but a HAT score of only five. However, it is acknowledged that this is only a single patient, and what is more, despite the high Barthel score, the patient remained an in-patient, deemed to require further rehabilitation. Looking at the HAT scores of patients lost to the study it was evident a high HAT score (median 9, range 6-10) was achieved prior to discharge home. This further highlights the limitations of the prospective sample, as all those with extreme HAT scores or functional outcome were lost to the analysis of recovery of head activity in this study.

Despite the lack of relationship between head activity and functional outcome found in this study, a link between head activity and severity and type of stroke was identified, and the evidence provided by the HAT results suggest that the head and trunk are inextricably linked during functional tasks. Added to the previously identified positive correlation between trunk control and sitting balance and functional outcome (e.g. Morgan, 1994; Ching-Lin et al., 2002) it remains reasonable to further test the hypothesis that early recovery of head activity is associated with good functional outcome. In order to do this, a larger sample of patients followed for longer and the careful choice of measure(s) of functional outcome are required.

6.4.6 Construct validity of the HAT

The hypothetical construct being assessed by the HAT is head activity, a new concept with no scale currently existing with which to measure it. Establishing the construct validity of the HAT is an ongoing process of learning more about head activity, making new predictions, and testing them. One challenge in establishing construct validity is that both the construct and the measure are being assessed at the same time. Therefore, if predictions made do not turn out to be true it is not known whether a) the scale is good but the construct is wrong, b) the theory is fine but the scale cannot discriminate, or c) both the construct is wrong and the scale is useless. Based on my theory of the construct 'head activity', I predicted that patients with a low score on the HAT would have more severe stroke, and have low scores on the Rivermead Motor Assessment Scale and Berg Balance Scale. This construct was supported by the work of this thesis. I also predicted that those who had low HAT scores in the first week following stroke would have lower functional and balance scores at week six than those with high initial HAT scores. This construct was not supported by the work in this thesis. It is evident from the results of the first study using the HAT that neither the construct of head activity nor that of the HAT as a good measurement tool can yet be confirmed, and further studies are required.

6.5 Patients' perception of head activity

The third contribution of this work has been the reporting of patient's perception of head activity and related sensations following stroke.

Patients showed minimal insight into any change in head activity that had occurred since their stroke, with a tendency to describe no difficulty with head activity even in the first week of recovery. Perhaps this is not surprising when we consider that head activity is not a term commonly used in everyday language, and that it is a complex construct, frequently not directly linked to goal achievement. In addition, it is likely that the patients' awareness of a problem is linked to the activities they have recently been undertaking at the time of being questioned. With abnormalities of head activity not being routinely addressed in therapy there seems little chance that patients will have insight into any deficit. This was highlighted when patients were asked about any balance problems they had. It was apparent that perceived difficulties with balance increased as the challenge of therapy advanced. It is important to understand the patient's insight into difficulties with head activity, as any intervention developed to address abnormalities of head activity would need to be explained to patients in terms that they could understand with respect to their recovery of function and goal achievement. This is imperative if patients are to be active participants in the treatment of abnormalities of head activity. Some patients did describe symptoms of abnormal head activity when describing difficulty with balance. It could be that by explaining the role of the head in balance control, and addressing head activity as part of an intervention to improve balance control, head activity would be most effectively managed. In comparison with the limited reporting of difficulty with head activity, headaches, episodes of dizziness, changes in vision, and shoulder and neck pain were more frequently reported throughout the six-week assessment period. Patients' experiences of these symptoms could provide further insight into possible mechanisms underlying abnormalities of head activity and postural control, and assist in the development of appropriate intervention strategies. Further exploration of patients' perceptions of difficulties with head activity and postural control is warranted.

6.6 Head activity used during a seated lateral reach

The fourth contribution of this work has been the detailed description of the head and trunk activity used by people with and without stroke during a seated lateral reaching task.

The results from the 3-D motion analysis study provide further detailed evidence of the abnormalities of head activity following stroke. The findings suggest that abnormalities of head activity during a lateral seated reach include sitting without alignment of the head and trunk, a lack of dissociation of the head and trunk demonstrated by a lack of counterbalancing with the head in the frontal plane, moving the head and trunk in stages rather than in a single continuous movement, and moving more slowly. What is not known from the detailed descriptions of head activity, however, are the mechanisms underlying these abnormalities. Cirstea and Levin (2000) suggested that the use of a compensatory trunk strategy when reaching to the impaired side might limit arm recovery following stroke. In contrast Robi-Bramy et al. (1997) suggested that increased trunk use might be a transitory adaptation providing for a better functional outcome. The picture is evidently not clear, and it may well be different for patients depending on the type and severity of stroke. The existence of a critical level of recovery linked with clinical severity of stroke has been proposed by Cirstea and Levin (2000). They suggest that the ability to carry out the given task with or without the use of a compensatory movement strategy may have prognostic implications. Below the threshold patients demonstrate compensatory movement patterns, while above the threshold, although patients may also compensate, they retain the ability to exploit normal movement patterns. It is possible that it is the latter group of patients that is most likely to improve. Whether this is applicable for the recovery of head and trunk movement following stroke is not known. Evidence is required from larger studies following patients through the acute phase of recovery, as to the existence of a critical level of recovery, and whether it is possible to identify early which patients retain the ability to use 'normal' movement patterns.

6.7 Theory generated from describing the head activity of patients following acute stroke

The findings of the work undertaken in this thesis investigating the head activity and its recovery following acute stroke support the following theory as a basis for future research:

That head and trunk position and movement are inextricably linked, and that it is not sound to separate either assessment or treatment of head and trunk activity following stroke.

The results from the studies in Sections 4A and 4B and Chapter 5 all suggest that head and trunk position and movement appear to be inextricably linked. However, the results also suggest that the link is not uniform, and that the relationship of the head relative to the trunk, and the head and trunk relative to the environment, are dependent on the nature of the challenge presented to postural control. It is apparent therefore that both head and trunk activity need to be assessed following stroke during tasks that present different challenges in relation to both the role of the head and the level of perturbation. The results from the three-dimensional motion analysis study (Chapter 5), and from using the HAT to characterise head activity in the first six weeks following stroke (Section 4B) indicate the existence of different patterns and levels of head and trunk dissociation depending on the task, its goal, and the level of the subject's head activity. A need is evident to characterise these different movement patterns, not only to accurately assess patients' head and trunk activity and postural control, but also to contribute to increasing our understanding of the possible mechanisms underpinning abnormalities of head and trunk activity following stroke, and to develop appropriate intervention strategies. To date, no clinical tool to assess head activity following acute stroke exists, and the tools currently available to assess trunk activity following stroke (Trunk Control Test, Collin and Wade (1990); Postural Assessment Stroke (PASS), Benaim et al. (1999); Trunk Impairment Scale (TIS), Verheyden et al. (2004)) do not include the assessment of head activity.

That head activity forms part of the hierarchical pattern of recovery of mobility following stroke, and that achievement of a critical level of head activity is required prior to the achievement of independent sitting balance, as rated with both a quality and dynamic element (e.g. Motor Assessment Scale, Carr and Shepherd, 1985).

Many clinical methods of rating sitting balance following stroke are available, though the majority rate the ability to sit independently, and do not rate the ability to function within the sitting position. Results from the patient study using the HAT (Section 4B) suggest that a critical level of head and trunk activity may be required to function within the sitting position. It is also suggested that the actual level of head activity achieved by a patient and/or time to achieve a set level of head and trunk activity could be of prognostic importance.

Further, that as evidence suggests that time to achieve independent sitting balance is associated with functional outcome (Wade et al., 1984; Bohannon, 1986; Sandin and Smith, 1990; Partridge et al., 1993; Morgan, 1994), and that level of trunk control at two weeks following stroke is associated with functional outcome at six months (Ching-Lin et al., 2002), early recovery of head activity is associated with good functional outcome.

This thinking is in line with that of the physiotherapy pioneers. They saw the ability to achieve a sitting position with an aligned head and trunk as a prerequisite to 'efficient' functional movement (Brunnstrom, 1970; Knott and Voss, 1968; Carr and Shepherd, 1987; Bobath, 1990). However, to date this remains unsubstantiated by evidence. It is perhaps most critical for patients to have the ability to dissociate head and trunk movement during performance of functional activities in the transition from being able to perform an activity (as assessed at activity level) to being able to function within the wider social context (participation level). The results of the patient study (presented in Section 4B) highlight the importance of the ability to dissociate head and trunk movement in tasks involving interaction with the environment, whether for vision or for social interaction. It is possible that this dissociation may make the difference between a patient being able to do a task in a controlled environment and actually performing the task in daily life. The ability to dissociate head and trunk movement could therefore be an issue in determining carry over of functional ability from within the therapy setting to outside of therapy, and on a larger scale, from hospital to home. It also follows that the ability to dissociate head and trunk movement could be a factor in determining which patients continue to progress outside of therapy, and those whose progress is halted, or even reversed, as the ability to dissociate head and trunk movement may affect the ability to cope with increased challenges of the non-therapeutic home environment.

The theory culminates in the hypothesis that early specific targeted interventions to improve recovery of head activity following stroke would

reduce the time to achieve independent and 'functional' sitting balance, <u>and</u> improve functional outcome.

It seems feasible to suggest that early specific targeted interventions to improve recovery of head activity following stroke could improve functional outcome following stroke. Characterising the specific patterns of head and trunk activity demonstrated during different tasks, and in different contexts, will play a role in identifying effective therapeutic interventions aimed at improving recovery of head activity following stroke. However, the gap in our knowledge of the role of the mechanisms underpinning abnormal head and trunk activity following stroke remains, and further understanding of these mechanisms in healthy adults and patients with stroke is vital to the development of effective interventions. The results from the patient study (Section 4B) suggest that effective interventions will need to be both task- and context-specific. This is in line with emerging new therapy approaches aimed at improving functional outcome following stroke.

6.8 Limitations of the work undertaken

In conducting the projects of this thesis numerous limitations were encountered. The limitations of each of the individual studies were discussed in the relevant chapters. In the following section the limitations of the work as a whole and the implications these have on the inferences that can be made are discussed.

6.8.1 Limitations within the HAT

In order to complete the HAT patients must be able to sit independently for one minute. This introduces a 'floor effect', and results in the head activity of all those without independent sitting balance scoring zero, and their head activity going un-rated. It is unlikely that this group of patients all have same level of head activity. For example, a patient with neglect (who is unable to sit) may demonstrate specific abnormalities in relation to difference between sides on the communication and visual search task not seen in a patient without neglect. In the HAT's current format the head activity of these two patients cannot be discriminated. In addition, if a patient who was unable to sit at the first assessment subsequently achieved independent sitting and was reassessed using the HAT, his or her HAT score could increase as head activity could be described for individual tasks, yet the actual head activity could remain unaltered from the first assessment. At the opposite end of the scale, having restricted the HAT to the assessment of head activity used during seated tasks, a 'ceiling effect' has also been introduced. In the patient study (presented in Section 4B), one patient scored a maximum of ten in the first week following stroke, despite being unable to walk independently. Though no abnormalities of head activity (as rated by the HAT) were demonstrated in sitting, it is not known whether this patient would have demonstrated abnormalities of head activity under more challenging circumstances, for example in standing, or when walking.

It is perhaps the 'floor effect' that is the greater of the two limitations. Certainly when looking at an early intervention for the treatment of abnormalities of head activity following stroke, patients with a tendency to the 'ceiling effect' would be unlikely targets for treatment, and not require serial assessment of head activity in sitting that was sensitive to change. In addressing the 'floor effect' there exists the potential to develop the HAT for use in supported sitting, though difficulties are likely to be encountered in defining what constitutes support. This would be an important achievement, as it is arguably these patients for whom an intervention is most needed. Having a tool to assess the head activity of patients unable to sit would allow any intervention used at the earliest stage of rehabilitation to be evaluated directly. Future research should also target the development of assessments of head activity in the more challenging positions of standing, and during gait.

The HAT is a grossly rated observational assessment tool. By the very nature of the rating method, the HAT results miss a wealth of information about the head activity demonstrated during the tasks. For example, during the visual search task there is the potential to define the actual number of degrees searched in each direction, and on each search attempt, allowing strategy consistency to be rated. However, a balance had to be struck between a method that could be used in the acute clinical setting with the potential for development into a clinical assessment tool, the detail of the data obtained by the tool, and the quality of the data. The gross rating system developed was feasible for use with video recordings, and tests of reliability and validity reached acceptable levels. It is this balance between the reliability and validity of the tool that is a crucial hurdle in tool development. For example, tools attempting to rate too much, and in too much detail, in an attempt to maximise content validity, can have great difficulty in reaching acceptable levels of reliability, as exemplified by the tool under development reported by Carr et al. (1995; 1999). On the other hand oversimplification of an assessment method may achieve excellent reliability, but the validity of the tool is challenged. It is hoped, (and the early results are supportive) that the HAT achieves the happy medium, with a balance between reliability and validity. Only with its further use on a larger and more varied sample will this be truly tested.

Rating head activity from video recordings also introduces the limitation of the type of observations that can be made. For example, it is not possible to describe eye movements from video recordings alone, and consequently the relationship between head and eye movements cannot be rated by the HAT. Specialised equipment such as three-dimensional video oculography is required to describe eye movements. Used in conjunction with three-dimensional motion analysis and linked video recordings, this equipment has the potential to describe head–eye and whole body movement coordination. Though clearly beyond the scope of the work undertaken in this thesis, such research would help to understand the mechanisms underlying head activity and abnormalities of head activity following stroke.

The HAT describes head activity during a one-off performance of the tasks, and the test–retest reliability of the HAT has not yet been established. The intervening factors of fatigue, practice, and recovery must all be factored in when the test–retest reliability of the HAT is established in the future.

The tasks that make up the HAT are by no means exhaustive. They were developed from those identified in the literature as being currently used in the assessment and treatment of head activity, but a very limited number of methods were found. It must be highlighted that the content validity of the HAT was limited to the knowledge base at the time of the tool development. However, the results from the first use of the HAT, with all but one patient failing to score maximally, and scores including the minimum, lend validity to the test procedure. The different roles of head activity are assessed but the choice of tasks was limited by the need to standardise the tasks. With further use of the HAT it is likely that some of the tasks will be refined, replaced or even dropped, as the results lead to further improvements to the HAT.

6.8.2 Limitations encountered in using the HAT

The HAT proved simple and easy to use in the acute clinical setting, and no problems were encountered with regard to patients understanding the tasks, or practically carrying out the assessment procedure. Whilst attempts were made to recruit a sample of healthy adults from the same age group of that affected by stroke, the samples from the two studies (Sections 4A and 4B) were not age matched. Campbell et al. (2001) found no age-related differences in patterns of head rotation used during a seated lateral reach, though significant age-related reductions in distance reached, speed of reach, and rotation of the pelvis were found. An age-matched control study is needed to distinguish more clearly, that changes in head activity as described by the HAT are a result of stroke and not due to the normal ageing process.

As is common to most research investigating the acute phase of recovery following stroke, the number and severity of patients recruited to the study introduced a major limitation to the conclusions that can be drawn from the results. The inclusion criteria, including the needs to pass a cognitive screening test and give informed consent, limited the sample by excluding those with most severe stroke. Confounding the limitations introduced by the small sample size was the prospective methodology used. Several patients were lost to the study in the six-week assessment period. A crucial limitation of the study design was not following up patients discharged home from hospital within the six weeks, resulting in a significant loss of patients to the prospective study. A further limitation was the length of time for which patients were followed. Having followed patients for six weeks it is evident that abnormalities of head activity remain apparent after this time. There remains the need to describe head activity and its recovery over a longer time frame, at least three months. Clinical experience suggests that reduced proximal stability, and an inability to move the head and trunk independently, can prevent individuals from achieving their maximum rehabilitation potential. In the researcher's experience, patients with sub-acute stroke frequently present with reduced ability to dissociate head and trunk movements, and have impaired postural control and functional ability. To date the longer-term consequences of reduced head activity remain unknown. The head activity of patients with more chronic stroke has not been investigated. It is not known whether early abnormalities remain long term, and whether they impact on patients' function and balance control. It is possible that reduced ability to dissociate head and trunk movements and a reliance on a head stabilisation on trunk strategy may increase the risk of falling following stroke. This would possibly become more apparent once the patient had been discharged from hospital, and needed to negotiate less controlled environments with greater distractions, both of which increase demands on balance.

6.8.3 Limitations encountered using Polaris

The limitations encountered using Polaris have been described previously in Sections 3.1.2.b and 5.4.8.c. It is worth stressing that at the time of the studies Polaris was the only available 3-dimensional portable motion analysis system available, and that this hugely influenced its use. However, considering the problems encountered with both its use and the interpretation of the data, it cannot be recommended for future use. In addition, limited previous work using Polaris in this field of study meant that there was no previous work to guide the data analysis and its interpretation. In future studies, the CODA system, used frequently in the analysis of human movement, which is now available as a portable system, would be recommended.

6.9 Clinical implications of the findings

In reflecting on the clinical implications of the work undertaken in this thesis, how therapists currently manage abnormalities of head activity following stroke was first considered. The situation to date is that, although head activity has been seen as important for some time (Brunnstrom, 1970; Knott and Voss, 1968; Carr and

Shepherd, 1987; Bobath, 1990; Chatterton et al., 2001; Tyson and De Souza, 2003), whether, and if so how, it is routinely assessed and/or treated is not known. Clinical experience, together with the early exploratory work undertaken in the development of the HAT, suggests that abnormalities of head activity are not routinely formally assessed or treated in patients following stroke. If treatment of head activity occurs at all, it is likely to be only on an ad-hoc basis. This is supported by the lack of an appropriate assessment tool, the minimal amount of published research on the topic, and no direct reference to head activity in clinical guidelines for treating patients with stroke. This raises the question as to whether current early therapy interventions adequately address head activity, and as a consequence proximal stability and postural control.

It is acknowledged that the findings from this work are early exploratory results, and the results from the patient study in particular (Section 4B) need to be confirmed with a larger and more varied sample, followed over a longer time period (see recommendations for future research, Section 6.10). However, the projects have highlighted areas for consideration in the development of early interventions for the treatment of abnormalities of head activity following stroke. This comes at a time when there is a huge push for evidence-based effective therapies for rehabilitation following stroke. The lack of proven therapies was highlighted by the recent clinical guidelines published by the Royal College of Physicians (Intercollegiate Working Party for stroke, 2004), and (in a concise format) by the Chartered Society of Physiotherapists (Hammond and Lennon, 2002). The guidelines do, however, lay the foundations for the development of novel interventions. How the findings of this work link with current guidelines, and the aspects of intervention the results highlight as having the potential for further exploration, are discussed in the following section.

6.9.1 Use of the HAT in the early assessment of patients with stroke

The HAT has potential for use as a clinical assessment tool, and proved to be appropriate for use in the acute clinical setting. The current Royal College of Physicians guidelines state, 'patients should be assessed by a physiotherapists within

72 hours of admission', and, 'where possible and available, clinicians should use assessments or measures that have been studied in terms of validity and reliability, and patients should be reassessed at appropriate intervals'. The HAT could play a part in assisting therapists to meet these two guidelines. The HAT is appropriate for use at this very early stage of rehabilitation, its validity and reliability have been established, and the early results suggest that it is sensitive to change. Recent findings by Ching-Lin et al. (2002) led the authors to suggest a need for the early assessment and treatment of trunk control in stroke patients. Sandin and Smith (1990) recommended the use of serial assessments of simple functional activities in the acute rehabilitation following stroke. The HAT could meet both these assessment recommendations in addition to that of assessing head activity suggested by this work.

6.9.2 Treatment of head activity following stroke

The availability of an appropriate assessment tool is a prerequisite to the development and implementation of treatment programmes addressing abnormalities of head activity following stroke, identifying which patients should be targeted for treatment, and measuring the efficacy of the intervention. The HAT has the potential to meet this requirement. There is currently an absence of specific clinical guidelines (above those of using any recognised treatment approach) for the early treatment of postural control deficits following stroke. No recommendations exist for early treatment of head activity. In light of the lack of recommendations, approaches to the treatment of head activity used for other pathologies could provide a useful starting point in the development of interventions specifically for patients with stroke.

Head movement exercises are commonly used in the treatment of balance disorders of vestibular origin (Herdman, 1994). Customised vestibular rehabilitation programmes include eye tracking exercises, and head and trunk exercises. Vestibular rehabilitation has been shown to be efficacious (but not universally) in patients with unilateral peripheral vestibulopathy or a central lesion (Girardi and Konrad, 1998; Shephard and Telian, 1996; Krebs et al., 2003). The mechanisms underlying any compensatory mechanisms obtained are, however, poorly understood and the outcome measures commonly used to assess the benefit of the programmes have been speed and stability during gait. Specific changes in eye, head, and trunk movement strategies have not been reported. Konrad et al. (1999) suggest that where deficits of balance control are multifaceted, therapy should include exercises for eye and head coordination with target changes, head movement with and without visual fixation, and sitting balance retraining. It is possible such an approach could be adapted to from part of an intervention for head activity following stroke. The HAT has the potential to be used to identify specific changes in head and trunk movement strategies following an intervention.

6.9.2.a Task-specific training

The HAT could also be useful as a tool for task-specific training. In the recent systematic review of the efficacy of physiotherapy interventions related to improving functional outcome following stroke (Van Peppen et al., 2004), all effective studies were characterised by focused exercise programmes within which the functional tasks were directly trained. Current clinical guidelines state that 'task-specific rather than impairment-focused should be used for the specific objectives of improved reaching for objects, and improved walking speed'. It is likely that over time the evidence of the benefit of task-specific training will increase, and guidelines will broaden to a greater number of tasks. The HAT, being comprised of functional tasks, lends itself to the identification of task-specific movement problems and the development of task-specific intervention programmes, and is an appropriate means by which the tasks could be serially reassessed. In terms of the current guidelines the HAT has direct application for reaching. The role of the HAT as a tool in the development of task-specific training approaches in other intervention studies, for example, visual search, communication and eating, requires further research.

6.9.2.b Multidisciplinary approach

Using the HAT tasks to guide therapy intervention would enable the development of treatment approaches that included tasks that patients could practise out of therapy, for example treatment strategies to use in the communication and eating tasks. Such an approach would meet the current clinical guideline that states, 'patients should be given as much opportunity as possible to practise tasks, and the team should promote the practice of skills gained in therapy into the patient's routine in a consistent manner'. The diversity of the tasks would also provide the opportunity for cross therapy working involving different members of the multidisciplinary team. A further guideline states, 'goal setting should involve the patient; goals should be set at the team level as well as by individual clinicians'. The HAT, with easily communicated meaningful results, and direct implications for therapy, lends itself to contributing to meeting this guideline. Carers could also potentially become involved specifically with treatments for patients with abnormalities of head activity during communication. Recommendations could include the position of the relative with respect to the patient, encouragement of eye contact, and orientation of the head. Again, this kind of approach would meet a current clinical guideline, 'all members of the health care team should work together with the patient and family'.

As already stated, no specific recommendations or clinical guidelines for treatment of head activity or early postural control deficits following stroke currently exist. As early postural control deficits are a common feature of stroke, and the preliminary studies in this work support existing evidence that abnormalities of head activity are common following stroke, this is clearly a shortcoming. Therapy interventions and guidelines need to be developed if treatment of head activity and postural control are to be targeted appropriately and effectively. The HAT has the potential to be used as a clinical assessment tool, to contribute to the identification of patients most appropriate for treatment, and to guide the development of task-specific therapy interventions for the treatment of abnormalities of head activity following acute stroke. Such assessment and treatment developments are needed, particularly in the very acute phase of recovery where patients have the greatest potential for recovery, and when costs to the nation (in terms of hospitalisation), and to the patients and their families are arguably at their greatest.

6.10 Recommendations for future research

The first recommendation for further research is to repeat the studies presented in Chapter 4 using a larger sample of patients, following all patients for 3 months, and recruiting an age-matched healthy adult sample. Within this study the hypothesis that the level of head activity in the first week following stroke is associated with functional outcome will be tested. Ethical approval has been granted for this study, which is to be funded by the Stroke Association.

As highlighted throughout the discussion, the HAT only provides a description of head activity. Further research is required to investigate the mechanisms that underpin head activity and postural control. In particular, the relationship between the coordinated movements of the eye, head, and whole body needs to be explored in both the healthy adult and patient populations through the use of detailed three-dimensional video-oculography and motion analysis. Understanding the mechanisms controlling head activity will enable new therapeutic interventions to be modelled.

With a view to the future development of a new intervention for the early treatment of abnormalities following stroke, further research is required to define current practice in the assessment and treatment of head activity following stroke.

The potential of the HAT to assess head activity used in supported sitting needs to be explored with further research. Likewise, further research is required to develop a clinical assessment tool to describe head activity used during tasks in the more challenging positions of standing, and while walking.

6.11 Concluding remarks

In this work the development of the HAT was described. Using the HAT for the first time, the head activity of a sample of healthy adults and patients with acute stroke was described. Those without stroke demonstrated a 'typical' pattern of head and trunk movement. The head activity of patients with acute stroke was characterised by difficulty in achieving an upright head and trunk position and difficulty dissociating head and trunk movement, resulting in a reluctance to move the head and/or trunk, and a lack of use of a head counterbalancing reaction. The patient with neglect demonstrated asymmetry of patterns of head activity between sides. In contrast to the healthy adult sample, variations between subjects were present in all tasks. Level of head activity (HAT score) following stroke was associated with type and severity of stroke. A significant increase in level of head activity was seen in the first six weeks following stroke, though again, variation in rate of change within the sample was a key feature. In depth three-dimensional motional analysis of a seated lateral reach confirmed the use of 'typical' head and trunk movement patterns in the healthy adult sample, and greater variation in the patterns used by patients following stroke. Features of the movement patterns used by patients while reaching included lack of head righting reaction with head stabilisation on the trunk, and reduced continuity of movement. Though this work is very much early exploratory work, it forms a crucial part of the pathway to the long-term goal of the development and implementation of an effective, targeted early therapeutic intervention for the recovery of head activity and postural control following stroke.

Appendices

List of Appendices

Appendix I

Protocol for the HAT

Patients will be recorded in unsupported sitting.
Unsupported sitting = sitting on a therapy plinth adjusted so that hips, knees, and ankles are at 90° with feet flat on the floor.

The video recorder will be situated on a tripod directly in front of the seated participant with the lens set to approximately eye level. The video recorder will be switched on prior to the start of the data collection. Recording will be paused using a remote control device. Tasks 1-3 (Upright sitting, visual search and communication tasks) and the lateral reach of task 5 (reaching task) will be recorded from in front of the participant. Task 4 (eating) and the forward reach of task 5 will be recorded from the side contra-lateral to the arm with which they are to reach. Participants will be aware that the researcher is interested in the way that they move but specific reference to head movement will not be made.

The five functional activities in sitting:

1. **Sitting position and corrected sitting position**

Participants will be requested by the researcher to sit "as upright as possible and hold for a count of ten".

2. **A visual search task.**

A system of seven small lights (LED's) mounted on the circumference of 2/3 of a circle of radius 1.50m will be mounted at individual eye level. The lights are situated at 45°, 90°, and 120° to either side of the mid point 0°. Participants will sit in the centre of the "circle". See Appendix I for diagram. The researcher will then randomly switch on one or none of the lights in the spatial range of 240°, (120° to the participants right and 120° to the participants left). Participants will be asked to "tell me how many red lights are on". The task will be repeated 6 times.

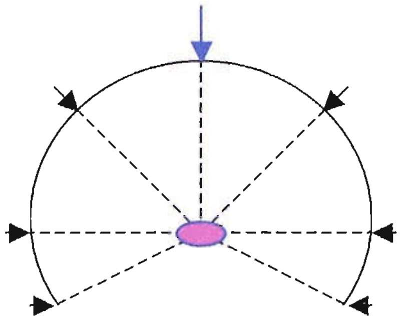
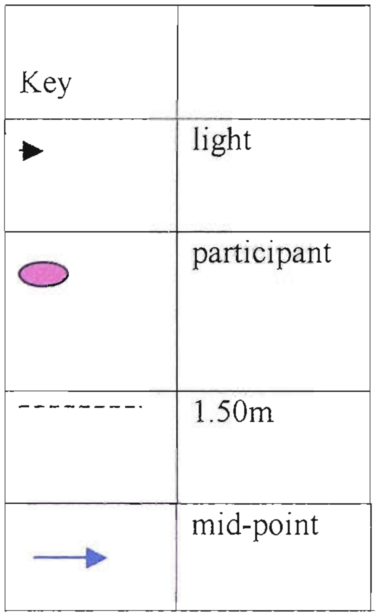

Figure A.1 Diagram of Visual Search Task

3. **Talking**

The researcher will sit opposite and at approximately 45° to one side of the participant. Participants will be asked some open questions about holidays that they have had. The task will be repeated with the interviewer sitting on the other side of the patient. The starting side will be randomly selected.

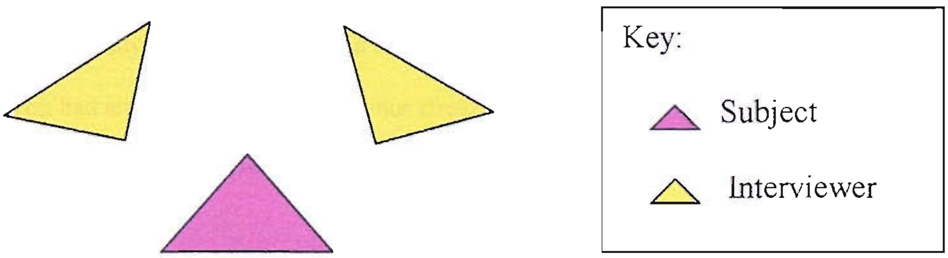

Figure A.2 Diagram of communication task

4. **Eating a yoghurt** (excluding patients with severe dysphagia)

Participants will be requested to eat three spoons of yoghurt using their dominant/unaffected hand. The yoghurt will be placed in a bowl on a height adjustable table in front of the participant on a non-slip mat.

5. **Reaching task**

Participants will reach with their dominant/unaffected arm. Participants' maximum dynamic forwards and lateral reach in sitting will be recorded using the portable functional reach test. Participants will be asked: "to reach as far forwards (or as far to the side) as you possibly can without over balancing and then return to the starting position.

Appendix IIa

Patient Interview Schedule

Assessment 1

1. Since you had your stroke do you have any difficulty moving your head?
2. Has your vision changed in any way since you had your stroke?
3. Since you had your stroke do you have any difficulty seeing things around you, (even with you glasses on)?
4. Have you ever had any difficulties with your hearing?
5. Do you hear better out of one ear than the other?
6. If so, Which one ?
7. Do you wear a hearing aid?
8. If so, In which ear?
9. Has your hearing changed at all since your stroke?
10. Have you ever had any neck pain?
11. Have you had any neck pain since your stroke?
12. Have you had any shoulder pain since your stroke?
13. Have you had any headaches since your stroke?
14. Have you had any difficulty with your balance since your stroke?
15. Have you had any episodes of dizziness since your stroke?

Assessment 2/3

1. In the last few days have you had any difficulty moving your head?
2. In the last few days have you had any difficulty seeing things around you?
3. In the last few days have you had any difficulty with your hearing?
4. In the last few days have you had any neck pain?
5. In the last few days have you had any shoulder pain?
6. In the last few days have you had any headaches?
7. In the last few days have you had any episodes of dizziness?
8. In the last few days have you had any difficulty with your balance?

Appendix IIb

Healthy Adult Interview Schedule

Assessment 1

1. Have you any problems with your vision?

2. Do you wear glasses?

3. Do you ever have difficulty moving your head?

4. Have you ever had any difficulties with your hearing?

5. Do you hear better out of one ear than the other?
   If so, which one?

6. Do you wear a hearing aid?
   If so, in which ear?

7. Have you ever had any neck pain?

8. Do you have any problems with your balance?

9. Do you ever have episodes of dizziness?

10. Do you suffer from headaches?

Assessment 2

Since the last time I assessed you has their been any change in your:

Vision?	Y/N
Hearing?	Y/N
Balance?	Y/N
Episodes of dizziness?	Y/N
Neck pain?	Y/N

Assessment 3

Since the last time I assessed you has their been any change in your :

Vision?	Y/N
Hearing?	Y/N
Balance?	Y/N
Episodes of dizziness?	Y/N
Neck pain?	Y/N

Appendix IIIa

Descriptors of head activity identified from the literature

Sitting/ corrected sitting position		
1. Asymmetry of trunk control	2. Trunk verticality	3. Head and thoracic spine extended
4. Neck: Neutral, Flexed, Extended	5. Trunk asymmetry: Leaning to affected side, unaffected side, Mid-line	6. Head rotation: affected side, unaffected side
7. Head lateral flexion affected side, unaffected side	8. Trunk rotation	9. Head adopts a midline posture
10. Trunk retraction	11. Trunk symmetry in frontal plane	12. Trunk symmetry in sagittal plane
13. Trunk lateral flexion	14. Shoulder protraction	

Visual Search		
1. Failure to search the left side /one side of space	2. Unable to gaze beyond midline	3. Turns head and trunk to look behind

Communication		
1. Flexion/extension	2. Amplitude of head movement	3. Use of hand gestures
4. Combined movements	5. Speed of head movement	6. Use of head movements as gestures
7. Rotation	8. Lateral tilt	

Eating		
1. Neutral head position on swallow	2. Chin up on swallow	3. Rotated to right on swallow
4. Chin-tuck on swallow	5. Rotated to left on swallow	

Forward Reach	Lateral Reach
1. Use of the head to counterbalance	1. Head moves outside of the pelvis in the lateral direction
2. Head righting reaction present	2. Trunk righting reaction present
3. Trunk righting reaction present	3. Head righting reaction present
4. Head on trunk stabilisation (head locked on the trunk)	4. Head on trunk stabilisation (head locked on the trunk)
5. Head stabilisation in space (dissociation of head and trunk movements)	5. Head stabilisation in space (dissociation of head and trunk movements)
	6. Use of the head to counterbalance

Appendix IIIb

Descriptors of head activity identified from clinical practise

Sitting posture	Corrected sitting
1. Head in relationship to trunk	1. Able to correct posture on command without excessive head extension
2. Unable to find middle	2. Corrects posture with head extension only (no trunk extension)
3. Fixing in postures	3. Over extension of the head used in attempt to compensate for lack of trunk extension
4. Head in front of pelvis	
5. Tilt, rotation, flexion/ext	
6. Chin tuck/jut	
7. Head hangs (nearly on chest)	
8. Deterioration of posture during activity (i.e. increasing task demand)	
9. Posture declines over (short) time	

Visual search		
1. Spontaneously follows activity	2. Looks to right more than left	3. Head position not enabling eyes to be directed to task
4. Moves on instruction only	5. Moves on instruction only	6. Speed-fast
7. Smooth	8. Following stimuli	9. Tight

Communication		
1. Spontaneous movement	2. Shrugs shoulders	3. Uses facial expression
4. Doesn't lift face	5. Head moves towards other? For hearing or gesture	6. Relaxed and varied head movements
7. Looks at other	8. Nodding	9. Lack of movement
10. Non-verbal gesturing	11. Lifts head and looks up when thinking	12. Maintains eye contact during conversation

Eating		
1. Head still for hand to mouth-lack of contributory movement	2. Moves head, trunk and hand in coordinated manner during eating i.e. head contributes to movement pattern	2. Movement of the body initiated by head movement

Forward reach	Lateral Reach
1. Head and trunk-rigid/fixed/solid/rod like/tree trunk like	1. Head and trunk-rigid/fixed/solid/rod like/tree trunk like
2. Maintains upright head posture during movement	2. Maintains upright head posture during movement
3. Uses head to counter balance movement of trunk	3. Uses head to counter balance movement of trunk
4. Head flopped in direction of reach	4. Head flopped in direction of reach
5. Head moves independently of trunk	5. Head moves independently of trunk
6. Head still when trunk moves – able to maintain gaze	6. Head still when trunk moves – able to maintain gaze
7. Righting reaction present/ not	7. Righting reaction present/ not
8. Some righting reaction but not normal	8. Some righting reaction but not normal

Appendix IIIc

Descriptors of head activity identified from clinicians

Sitting Position	Corrected sitting
1. Flexed trunk and slumped sitting	2. Head did not move
3. Head rotated and side flexed away from affected side	4. Pushing through good side
5. Posterior pelvic tilt	6. Head extension and chin protraction
7. Protracted head posture with cervico-thoracic flexion	8. Fixes head and moves pelvis only
9. Posturing in side flexion away form affected side	10. Uses eyes in an attempt to move
11. Posturing in rotation away form affected side	12. Hyperactive shoulder elevation
	13. Neutral head position
	14. Use of excessive cervical extension and retraction to recruit trunk extension
	15. Neck flexion to initiate trunk flexion
	16. Head not used to correct sitting

Visual Search	
1. Head rotation with shoulder elevation	2. Head rotation with trunk rotation and extension
3. Reduced head rotation compensated for by trunk rotation in either or both directions	4. Head rotation with contra-lateral lateral tilt
5. Head rotation with chin protraction	6. Eye movement preceded head rotation
7. Increased trunk extension whilst searching	8. End of range neck rotation with increased shoulder elevation and trunk rotation
9. Neck +/- trunk extension on end of range rotation	10. Rotating to one side only
11. Reduced rotation of head to one side	

Communication	
1. Head flexion towards talking side	2. Head flexion towards the opposite side whilst rotated to the side of talking
3. Head rotation to talking side	4. Head flexion and rotation to the talking side
5. Shoulder elevation	6. Trunk and head rotation to the talking side (trunk follows where head goes)
7. No eye contact	8. Head side flexion away from talking side with rotation towards talking side (possibly fixing with upper traps)
9. Use of arms for gesturing	10. Facial expression with conversation
11. Reduced maintenance of rotation when talking towards affected side (tending to take head back to neutral several times)	12. Reduced automatic head movements when talking on affected side

13. Nodding and shaking when facing both sides	14. Reduced fluidity of head movement
15. Trunk rotation in same direction as head rotation	16. Flexed trunk with protracted head posture

Eating	
1. No head movement	2. No head or trunk movement
3. Lateral tilt of head away from feeding arm (to affected side)	4. Head extension and trunk flexion
5. Head and trunk flexion	6. Rotation of head to feeding arm (to unaffected side)
7. Increased trunk flexion to compensate for reduced head movement	8. Increased arm to mouth activity to compensate for reduced head movement
9. Trunk flexion with reduced arm and head movement	10. Cervical flexion to swallow
11. Cervical spine extension/protraction of head to bring spoon to mouth	

Forward Reach	**Lateral Reach**
1. Reduced trunk extension on forwards reach	1. Head, neck and trunk move as block
2. Head, neck and trunk move as block	2. Increased shoulder elevation
3. Reduced righting reaction	3. Reduced righting reaction
4. Head and trunk move together (fixation)	4. Reduced trunk elongation
5. Upper and lower cervical extension on reaching forwards	5. Overcompensates after reach (rocks from side to side)
6. Reduced head extension	6. Lack of opposite head side flexion
7. Lack of trunk extension compensated for by neck hyper extension	7. Cervical extension to maintain trunk position in lateral reach
	8. Head stays midline
	9. Head rotated away from reaching arm but not side flexed away

Appendix IIId

Descriptors of head activity identified from the researchers

Sitting Position	Corrected sitting
1. Able to sit unsupported	1. Attempt made to correct posture
2. Trunk alignment	2. Position improved/ same / worse
3. Head on trunk alignment	3. Selective trunk extension demonstrated
	4. Push into extension with the head
	5. Able to maintain corrected position/ gradual loss of corrected position
	6. Trunk alignment in corrected position
	7. Head on trunk alignment

Visual Search	
1. Eye movement alone	2. Head and trunk rotation
3. Just head rotation (and eye movement)	4. Pushes with arms on knees
5. Leaning backwards whilst looking	6. Looks both to left and right
7. Stable whilst searching	8. Does not return head to midline
9. Single search in each direction/repeated for individual tests	10. Head and trunk rotation accompanied by head and trunk flexion
11. Does not return trunk to midline	12. Smooth movement or jumping light to light
13. Speed of searching	14. Amount of head rotation
15. Starting posture	16. Eyes move first
17. Shoulder asymmetry	

Communication	
1. Looks at interviewer when on right and left	2. Looks around whilst thinking
3. Nodding and shaking of head appropriately/ minimally/not at all	4. Not moving head at all
5. Trunk movement with conversation	6. Fixed gaze on interviewer throughout
7. Head held flexion, no eye contact	8. Upper limb gestures /movements
9. Gaze not fixed, breaks but returns	10. Upper limbs used for support
11. Shoulder shrugs demonstrated	12. Upper limbs used for support
13. Forward poking chin	14. Remains in same position as listener moves
15. Symmetry of shoulders	16. Talks whilst turned away from interviewer

Eating	
1. Head and trunk flexion	2. Just head movement
3. No trunk or head movement	4. No head extension with trunk flexion
5. Appeared effortful	6. Leaning backwards
7. Overuse of arm with spoon	8. Looks at food
9. Head tilt towards feeding side	10. Head midline
11. Head extension or not when spoon enters mouth	12. Spoon to mouth or mouth to spoon
13. At least a right angle between neck and head when spoon enters mouth	14. "Packer" repetitive rapid feeder
15. Big high feeding arm	

Forward Reach	Lateral Reach
1. Alignment of trunk	1. Alignment of trunk
2. Alignment of head on trunk	2. Alignment of head on trunk
3. Maintains extension of head during reach	3. Counter balancing with the head 4. (Lateral flexion of the head in the opposite direction)
4. Head fixed to trunk	5. Head fixed to trunk
5. Head remains vertical in space	6. Head remains vertical in space
6. Head tilt/rotation	7. Flexion / extension of the head
	8. Flexion / extension of the trunk
7. Head compensates for lack of trunk movement	9. Head compensates for lack of trunk movement
8. Speed of movement	10. Speed of movement
9. Return to a point beyond midline then correct or not (unaware of distance moved)	11. Return to a point beyond/not midline then correct or not (unaware of distance moved)
10. Unaware of risk	12. Looks at hand
11. Fixing of gaze	13. Fixing of gaze
12. Stiff/rigid head	14. Stiff/rigid head
13. Distance reached	15. Distance reached
14. Lack of facial expression	16. Weight transference
15. Smooth /moves in stages	17. Smooth /moves in stages
16. Head does not initiate movement	18. Unable to isolate lateral movement
	19. Lack of facial expression
	20. Head does not initiate movement
	21. Unaware of risk

Appendix IIIe

Descriptors of head activity identified from the patients

Sitting position	
1. Patient seems unaware of their position	2. Leaning one way
3. Off balance	4. Wobbly
5. Unbalanced when not supported	

Visual search task	
1. Difficulty seeing/focusing on targets	2. Repeated searches for individual targets required

Appendix IV

The HAT - Guidelines for use and definitions of terms

Please tick the appropriate box for each section.

Ensure subjects wear any glasses and hearing aids as normal

Upright Sitting

1. **Attempt made to correct**

Movement of the body in an attempt to adjust to a more upright sitting position

If Yes

- **Selective Movement:** Selective trunk extension used to adjust position. No apparent over activity or mass movement (for example, pushing into extension with head, trunk or limbs) seen.

2. **Trunk upright**

The trunk is in a vertical, midline position with respect to the frontal, sagittal, and transverse planes. I.e. no significant degree of flexion/extension, side flexion, rotation, or any combination is present. If borderline rate as upright.

3. **Head upright**

The head is in a vertical, midline position with respect to the frontal, sagittal, and transverse planes. If borderline rate as upright.

If No

- **Flexion:** The subject's face is not in full view with face and eyes directed towards the floor.
- **Protraction/extension:** The subject has marked forwards poking of the chin with upper cervical extension
- **Side flexion:** The position is that of side flexion, or predominantly side flexion if in a combined position. Note direction of side flexion.

- **Rotation:** The position is that of rotation, with the whole face (including ears) no longer in view, or predominantly rotation if in a combined position. Note direction of rotation.

If rated as upright trunk and head

4. Maintained

Subject maintains the upright position for at least ten seconds.

Visual Search

5. Search strategy

- **Head moves both ways:** Subject rotates head to both left and right whilst completing search to both sides.
- **Head moves only one-way:** Subject rotates head to one side only whilst completing search (specify direction of rotation). I.e. no rotation of the head beyond midline in one direction.
- **Incomplete search:** Subject fails to complete search to either side. Include those who do not attempt to search

6. Trunk movement: The trunk moves whilst the subject searches.

If Yes

- **Head and trunk rigid:** Head and trunk is rod like, moving as a block.
- **Head and trunk move freely:** Head and trunk both move but in a coordinated manner, with the head moving freely on the moving trunk.

Talking

7. Orientation of the head

Rate conversation with interviewer sitting on the **Right** and **Left** of the subject separately.

- **Away:** During the conversation the subject DOES NOT orientate their head and face towards the interviewer at any point.
- **Towards:** During the conversation the subject orientates their head and face towards the interviewer throughout. No change in the direction the subject faces occurs at any point.
- **Towards and away:** During the conversation the subject uses a variety of head positions including time facing the interviewer.

8. **Use of head for gestures:** Head movement is used for speech emphasis, as gesture, or any other form of non-verbal communication. For example the use of nodding and shaking the head or tilting the head towards the interviewer.

If Yes

- **Frequent and large:** The subject moves their head as a form of non-verbal communication throughout the conversation using a variety of movements, at least one of which is large in amplitude (e.g. repeated nodding)
- **Moderate:** The head is moved occasionally during the conversation using a variety of movements, at least one of which is large in amplitude **or** the head is moved throughout the conversation but all movements are small.
- **Minimal and small:** The head is predominantly still. Any movement seen is small (e.g. single nod).

Eating

9. Feeding action

- **Arm only:** No significant head or trunk movement making up the food to mouth action.
- **Head to pot:** Large amount of head and trunk flexion necessitating only minimal arm movement for the food to mouth action
- **Meet in the middle**: Food enters the mouth following coordinated movement of trunk flexion, head extension and upper limb elevation.

Reaching

10. Counter balance with head: Head moves in opposite direction to the trunk, i.e. head righting reaction demonstrated.

- **Lateral reach:** Head side flexion is in the opposite direction to reach bringing the head into an approximately upright position
- **Forward reach:** Head extension accompanies trunk flexion bringing the head into an approximately upright position.

Appendix V

Defining the HAT lateral reach rating category boundaries

An example of how the HAT category boundaries were defined for rating the tool item 'counterbalances with the head' on the lateral reach task is explained in detail below.

Step 1:

The guidelines for rating the tool item 'counter balances with head' on the lateral reach state to rate as ***yes*** if "the head moves in the opposite direction to the trunk, i.e. head roll is in the opposite direction to the reach in an attempt to counterbalance the reach". Using these rating guidelines the Polaris data sets required to define the Polaris boundaries for this tool item were identified as:

i. 'Head relative to trunk' - to describe the direction and amplitude of head rotation in relation to the trunk (direction of trunk movement already being known),

ii. 'Head relative to the fixed room reference' - to describe whether the movement counterbalances the reach. The rotation required in both instances was *roll* (rotation in the frontal plane /side-flexion).

Step 2:

The Polaris results for the healthy adult lateral reach were analysed. The results were grouped in terms of the HAT rating, i.e. those rated as "***yes***" (demonstrating a counter balancing reaction with the head), and those rated as "***no***" (not demonstrating a counter balancing reaction with the head). Five out of the six healthy adults demonstrated a counter balancing reaction with the head, therefore, the mean and two standard deviations of the Polaris results from the healthy adult sample rated as "**yes**" (with the HAT) for *roll* of the head relative to the trunk, and *roll* of the head relative to the fixed room reference were calculated (the results are presented in table AV.2).

	Head relative trunk	Head relative fixed reference
Mean amplitude of roll	16°	5°
Range of roll	13°- 22°	2°- 8°
Standard deviation	4.0	2.3
Two standard deviations	8.0	4.6

Table AV.1 Polaris data for the lateral reach test of the Healthy adult's rated as demonstrating counter balancing with the head.

The boundaries for the "**yes**" category could now be quantified; the "**no**" category was simply defined as not fitting both the "**yes**" boundary definitions. The boundaries for the lateral reaching task are presented in table AV.2.

Lateral reach	HAT rating category	Definition of Polaris category boundaries
Counterbalances with head	**YES**	Head relative trunk: ≥ 8° (16-8) roll from the starting position in the opposite direction to trunk rotation. Head relative fixed: At the peak of the reach (time of maximum trunk roll) head roll is ≤10° (5+4.6) from neutral.
	NO	Failure to meet both "YES" category boundary criteria

Table AV.2. Polaris boundaries for the lateral reaching task

Appendix VI

Ranges of cervical movement

Definition of within aged-matched "normal" range

Range of movement was measured for the six directions of movement. Active range of movement in supported sitting was assessed first. Where active range was less than the "normal" range passive range was tested.

"Normal" range for this study was defined as within the 95% confidence interval of range of movement as described by Kuhlman (1993) in a study of cervical range of movement in the elderly (70-90 years).

Movement	**"Normal" range in degrees**
Flexion	54-67
Extension	45-57
Right rotation	67-77
Left rotation	65-79
Right side flexion	31-40
Left side flexion	33-39

Ref:

Kuhlman, K. A. (1993). Cervical range of motion in the elderly. Archives of Physical Medicine and Rehabilitation, 74, 1071-1079.

Poole Hospital NHS
NHS Trust

Appendix VII a

Longfleet Road
Poole
Dorset
BH15 2JB

Tel: 01202 665511
www.poolehos.org

Our Ref: SW.RCH/LREC 43/01/S

20 July 2001

Ms K Jupp, Student
University Rehabilitation Research Unit
Level E, Centre Block
Southampton General Hospital
Tremona Road
SOUTHAMPTON SO16 6YD

Dear Ms Jupp

Head postures & movements used during functional activities in sitting by people following acute stroke
LREC NO : 43/01/S [must be quoted in all correspondence]

The East Dorset Local Research Ethics Committee met on 19 July 2001. They considered your response dated 21 June 2001 and were satisfied with your response.

Ethical approval was therefore granted.

Present at the meeting :

S Wheeler	M Leggett	R Day	J Begley	B J Waltho
G Roberts	S Elliot	T Hamblin	D Tory	T Hollingberry
C Maunder				

In Attendance : R Hanson

Conditions of approval are set out in the attached sheet.
Protocol amendments must be précised onto one page and accompany original documentation.
Serious Adverse Events must be summarised onto the attached form and accompany original documentation.

Yours sincerely

RACHAEL HANSON
ADMINISTRATOR, EAST DORSET LOCAL RESEARCH ETHICS COMMITTEE

Appendix VII b

The Royal Bournemouth and Christchurch Hospitals
NHS Trust

NHS

☎ 01202 704452 (Direct Line)
01202 704077 (Fax)
email: simon.dursley@rbch-tr.swest.nhs.uk
POST POINT B28

The Royal Bournemouth Hospital
Castle Lane East
Bournemouth
BH7 7DW

01202 303626
www.rbh.org.uk

SCD/PLH/research2001\JUPP22.01

4th September 2001

Ms Kate Jupp
University Rehabilitation Research Unit
Level E, Centre Block
Southampton General Hospital
Tremona Road
Southampton
S016 6YD

Dear Mrs Jupp,

RESEARCH PROJECT : RE 22/01(RBH)
(Please quote the RE number on all future correspondence relating to this project)

OBSERVATIONAL STUDY OF HEAD ACTIVITY FOLLOWING STROKE

The Trust's Research Committee has approved the above project, subject to the following conditions:-

(i) approval of the project on ethical grounds by the East Dorset LREC;

(ii) you must satisfy the Financial Accountant, Mr Keith Skillings (Ext. 4480), prior to the project commencing, on all its financial implications. In particular, you must confirm that any additional activity over and above routine care, e.g. additional outpatient attendances/tests, has been discussed with and has the approval of the relevant Head of Department and will be fully funded by payments to the relevant departments. You must also be able to satisfy Mr Skillings as to how that will be done;

(iii) you must send to the Financial Accountant, annually and at the conclusion of the project, an Income and Expenditure account.
N.B. *The Trust Board regard this condition as mandatory and any failure to comply with it will be taken into account when any future Research applications are considered; and*

/...2

(iv) you must submit a report to me, at the conclusion of the project, setting out the results achieved from it. This report will be for the information of our own Committee and also the LREC.

Yours sincerely,

SIMON DURSLEY
TRUST SECRETARY

c.c. Stephanie Wheeler, Chairman, East Dorset LREC, Poole Hospital NHS Trust
Keith Skillings, Financial Accountant, RBH
Sandy Edington, General Manager, Christchurch Hospital

Appendix VII c

East Dorset Local NHS
Research Ethics Committee

Administrator: Rachael Hanson
Poole Hospital NHS Trust
Longfleet Road
Poole
Dorset
BH15 2JB

Tel: 01202 448201
Fax: 01202 442954
e-mail: rhanson@poole-tr.swest.nhs.uk

Our Ref : SW/RCH/LREC 24/02/S

31 May 2002

Mrs Kate Jupp,
University Rehabilitation Research Unit
Southampton General Hospital
Southampton
Hants
SO16 6YD

Dear Mrs Jupp

Head position and movement during functional activities in sitting in people following acute stroke : Measurement and change over time

Amended patient information sheet

The East Dorset Local Research Ethics Committee met on 30 May 2002.

They noted your revised Patient Information Sheet which was satisfactory.

DECISION : APPROVED

Present at the meeting :

S Wheeler, Chair	R Day, Vice-Chair	B J Waltho	M Leggett
M Burrows	T Hamblin	D Tory	A Drury
S Elliott	D Jones		

In Attendance : R Hanson, Administrator

Conditions of approval are set out in the attached sheet.
Protocol amendments should be precised onto one page and accompany any documentation.
Serious Adverse Events should be listed on the attached form and accompany any documentation.

Yours sincerely

Rachael Hanson
Administrator, East Dorset Local Research Ethics Committee

The Royal Bournemouth and Christchurch Hospitals NHS Trust

Appendix VII d

☎ 01202 704452 (Direct Line)
01202 704077 (Fax)
email: simon.dursley@rbch-tr.swest.nhs.uk
POST POINT B28

The Royal Bournemouth Hospital
Castle Lane East
Bournemouth
BH7 7DW

01202 303626
www.rbh.org.uk

SCD/PLH/research2002/Jupp 24.02

28th June 2002

Mrs Kate Jupp
Student
University of Southampton
Rehabilitation Research Unit
Centre Block, Level E
Southampton General Hospital
Tremona Road
Southampton SO16 6YD

Dear Kate

RESEARCH PROJECT : RE 24/02(RBH)
(Please quote the RE number on all future correspondence relating to this project)

HEAD POSITION AND MOVEMENT DURING FUNCTIONAL ACTIVITIES IN SITTING IN PEOPLE FOLLOWING ACUTE STROKE: MEASUREMENT AND CHANGE OVER TIME

The Trust's Research Committee has approved the above project, subject to the following conditions:-

(i) approval of the project on ethical grounds by the East Dorset LREC; and

(ii) you must submit a report to me, at the conclusion of the project, setting out the results achieved from it. This report will be for the information of our own Committee and also the LREC.

Yours sincerely

SIMON DURSLEY
TRUST SECRETARY

c.c. Stephanie Wheeler, Chairman, East Dorset LREC, Poole Hospital NHS Trust
Sandy Edington, General Manager, Christchurch Hospital

Appendix VIIIa

Health and Rehabilitation Research Unit

Professor Ann Ashburn
PhD MPhil MCSP
Head of Unit

School of Health Professions and Rehabilitation Sciences

Professor R E Barnitt
PhD MSc FCOT
Head of School

Level E, Centre Block
(Mailpoint 886)
Southampton General Hospital
Tremona Road
Southampton
SO16 6YD
United Kingdom

Telephone +44 (0)23 8079 6469
Fax +44 (0)23 8079 4340
Email A.M.Ashburn@soton.ac.uk
WWW http://www.sohp.ac.uk/sohp/

Head postures and movements during activities in sitting used by people following stroke: LREC 43/01/S

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with your relatives or members of staff if you wish. Please ask us if there is anything that is not clear or if you would like more information. This Information Sheet is for you to keep. Please take time to decide whether or not you wish to take part.

We need to know more about the affect a stroke has on head movement. In order to do this we need to compare the head movement of people who have, and have not had a stroke. The aim of this study, which is being funded by the Stroke Association, is to increase our understanding of head movement following stroke.

The study will take place on the stroke unit. If you decide to take part the researcher will take short video recordings looking at your movement and balance whilst you do five activities. These activities are, holding a conversation, eating a meal, sitting quietly, and carrying out a sorting task and a visual search task. You will also be asked a few questions about your hearing and vision. The total time of the study will be approximately one hour at a time of day to suit you. All the information that is collected about you during the course of the study will be kept strictly confidential. Your GP will be notified of your participation in the study.

If you decide to take part, you are free to withdraw from the study at any time and without giving a reason.

Thank you for considering taking part in the study.

For further information please contact,

Kate Jupp
Research Physiotherapist
University Rehabilitation Unit Southampton General Hospital
Telephone; 023 80 798669

Health and Rehabilitation Research Unit

Professor Ann Ashburn
PhD MPhil MCSP
Head of Unit

School of Health Professions and Rehabilitation Sciences

Professor R E Barnitt
PhD MSc FCOT
Head of School

Level E, Centre Block
(Mailpoint 886)
Southampton General Hospital
Tremona Road
Southampton
SO16 6YD
United Kingdom

Telephone +44 (0)23 8079 6469
Fax +44 (0)23 8079 4340
Email A.M.Ashburn@soton.ac.uk
WWW http://www.sohp.ac.uk/sohp/

Head postures and movements during activities in sitting used by people following stroke. LREC 24/02/S

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with your relatives or members of staff if you wish. Please ask us if there is anything that is not clear or if you would like more information. This Information Sheet is for you to keep. Please take time to decide whether or not you wish to take part.

We need to know more about the affect a stroke has on head movement. In order to do this we need to compare the head movement of people who have, and have not had a stroke. The aim of this study, which is being funded by the Stroke Association, is to increase our understanding of head movement following stroke.

The study will take place on the stroke unit. If you decide to take part the researcher will take short video recordings of your movement and balance whilst you do five activities. These activities are, holding a conversation, eating a yoghurt, sitting quietly, reaching and carrying out a visual search task. The video recording will take approximately twenty minutes. If it is possible, the recordings will be repeated on two further occasions. These sessions will be on different days, at times to suit you. On each of these occasions the five activities will be recorded on video. In addition during the first session you will be asked a few questions about your hearing and vision. The information that is collected will be kept strictly confidential.

If you decide to take part, you are free to withdraw from the study at any time and without giving a reason.

Thank you for considering taking part in the study.

If I am not on the ward, please leave a message for me at the nurses' desk, or contact,

Kate Jupp
Research Physiotherapist
University Rehabilitation Unit
Southampton General Hospital
Telephone: 023 80 79866

Health and Rehabilitation Research Unit

Professor Ann Ashburn
PhD MPhil MCSP
Head of Unit

School of Health Professions and Rehabilitation Sciences

Professor R E Barnitt
PhD MSc FCOT
Head of School

Level E, Centre Block
(Mailpoint 886)
Southampton General Hospital
Tremona Road
Southampton
SO16 6YD
United Kingdom

Telephone +44 (0)23 8079 6469
Fax +44 (0)23 8079 4340
Email A.M.Ashburn@soton.ac.uk
WWW http://www.sohp.ac.uk/sohp/

LREC NO 43/01/S

Head postures and movements during activities in sitting used by people following stroke.

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with your relatives or members of staff if you wish. Please ask us if there is anything that is not clear or if you would like more information. This Patient Information Sheet is for you to keep. Please take time to decide whether or not you wish to take part.
We need to know more about the affect a stroke has on head movement. The aim of this study, which is being funded by the Stroke Association, is to increase our understanding of head movement following stroke.

The study will take place on the stroke unit. If you decide to take part the researcher will spend time with you on one day. You will be asked a few questions about your stroke and how you feel it affects your movement and balance. During the day the researcher will take short video recordings looking at your movement and balance whilst you do five activities and during one therapy session. These activities are, holding a conversation, eating a meal, sitting quietly, and carrying out a sorting task and a visual search task. The timing of these video recordings will take place to fit in with your daily timetable. In total the time you will spend in the study will be approximately one hour, but this may well be spread throughout the whole day depending on your routine.

All the information that is collected about you during the course of the study will be kept strictly confidential. Any information about you that leaves the hospital will have your name and address removed so that you cannot be recognised from it. Your GP will be notified of your participation in the study.

If you decide to take part, you are free to withdraw from the study at any time and without giving a reason. This will not affect your care in any way.Thank you for considering taking part in the study.

For further information please contact,

Kate Jupp
Research Physiotherapist
University Rehabilitation Unit Southampton General Hospital
Telephone; 023 80 798669

Appendix VIIId

Health and Rehabilitation Research Unit

Professor Ann Ashburn
PhD MPhil MCSP
Head of Unit

School of Health Professions and Rehabilitation Sciences

Professor R E Barnitt
PhD MSc FCOT
Head of School

Level E, Centre Block
(Mailpoint 886)
Southampton General Hospital
Tremona Road
Southampton
SO16 6YD
United Kingdom

Telephone +44 (0)23 8079 6469
Fax +44 (0)23 8079 4340
Email A.M.Ashburn@soton.ac.uk
WWW http://www.sohp.ac.uk/sohp/

Patient Information Sheet

May 2003

Recovery of head movement following stroke

LREC NO 24/02/S

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with your relatives or members of staff if you wish. Please ask if there is anything that is not clear, and take time to decide whether or not you wish to take part. Consumers for ethics in research publish a leaflet entitled 'Medical Research and You'. This leaflet gives more information and looks at some questions you may want to ask. A copy may be obtained from CERES, PO Box 1365, and London N16 0BW. Thank you for reading this.

What is the purpose of this study?
We need to know more about the affect a stroke has on head movement. The aim of this study six-month study is to increase our understanding of the recovery of head movement following stroke.

Why Have I been chosen?
All patients admitted to hospital over a six-month period, who have had a first stroke and meet the study criteria will be invited to take part in the study. It is estimated that 50 patients in total will take part.

Do I have to take part?
If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form, of which you will also be given a copy to keep. You are free to withdraw from the study at any time without giving a reason. This will not affect your care in any way.

What will happen to me if I take part?
The study will take place on the ward. If you decide to take part the researcher will spend time with you on three separate occasions. These occasions will be in the first, third and sixth week following your stroke. On each occasion the following assessments will be made.

- You will be asked a few questions about how you feel having a stroke has affected your movement and balance.
- Your movement, balance and function will be assessed.
- A short video recording of your movement and balance whilst you do five activities in sitting will be taken. These activities are: talking, eating, sitting quietly, reaching, and a visual search task.

The timing of these assessments will take place to suit you and fit in with your daily timetable. The time you will spend in the study will be approximately one hour on the three separate occasions.

What are the possible benefits of taking part?
There will be no clinical benefit to you from taking part in this study. The information we get from this study may help us to treat future patients who have had a stroke better.

Will my taking part in this study be kept confidential?
All the information that is collected during the course of the study will be kept strictly confidential and your name and address will be removed from any information about you that leaves the hospital. Your GP will be notified of your participation in the study.

What will happen to the results of the research study?
The results of the study will be presented and published locally, nationally, and internationally. All participants will receive a letter summarising the results on completion of the study in 2003. Participants will not be identified in any report or publication.

Who is organising and funding the research?
The Stroke Association is funding this study.

Who has reviewed the study?
East Dorset Research Ethics Committee and the Royal Bournemouth and Christchurch Hospital have granted approval for the study.

Thank you for considering taking part in the study.
For further information please contact,

Kate Jupp
(Research Physiotherapist)

Appendix IXa

Health and Rehabilitation Research Unit

Professor Ann Ashburn
PhD MPhil MCSP
Head of Unit

School of Health Professions and Rehabilitation Sciences

Professor R E Barnitt
PhD MSc FCOT
Head of School

Level E, Centre Block
(Mailpoint 886)
Southampton General Hospital
Tremona Road
Southampton
SO16 6YD
United Kingdom

Telephone +44 (0)23 8079 6469
Fax +44 (0)23 8079 4340
Email A.M.Ashburn@soton.ac.uk
WWW http://www.sohp.ac.uk/sohp/

CONSENT FORM

Head postures and movements during activities in sitting used by people following stroke. LREC NO 43/01/S

Name of Researcher: Kate Jupp **Patient Identification Number:**

Please tick the boxes as appropriate

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐

4. I agree to take part in the above study ☐

5. I agree to video recordings being taken of me during the study. ☐

6. I agree to the videos being shown for educational purposes to medical audiences. ☐

____
Name of volunteer

____________________ ____________________
Signature of volunteer Date

____________________ ____________________
Signature of researcher Date

Health and Rehabilitation Research Unit

Professor Ann Ashburn
PhD MPhil MCSP
Head of Unit

School of Health Professions and Rehabilitation Sciences

Professor R E Barnitt
PhD MSc FCOT
Head of School

Level E, Centre Block
(Mailpoint 886)
Southampton General Hospital
Tremona Road
Southampton
SO16 6YD
United Kingdom

Telephone +44 (0)23 8079 6469
Fax +44 (0)23 8079 4340
Email A.M.Ashburn@soton.ac.uk
WWW http://www.sohp.ac.uk/sohp/

CONSENT FORM

Head postures and movements during activities in sitting used by people following stroke. LREC NO 24/02/S

Name of Researcher: Kate Jupp **Patient Identification Number:**

Please tick the boxes as appropriate

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐

4. I agree to take part in the above study ☐

5. I agree to video recordings being taken of me during the study. ☐

6. I agree to the videos being shown for educational purposes to medical audiences. ☐

____
Name of volunteer

______________________ ______________________
Signature of volunteer Date

______________________ ______________________
Signature of researcher Date

Health and Rehabilitation Research Unit

Professor Ann Ashburn
PhD MPhil MCSP
Head of Unit

School of Health Professions and Rehabilitation Sciences

Professor R E Barnitt
PhD MSc FCOT
Head of School

Level E, Centre Block
(Mailpoint 886)
Southampton General Hospital
Tremona Road
Southampton
SO16 6YD
United Kingdom

Telephone +44 (0)23 8079 6469
Fax +44 (0)23 8079 4340
Email A.M.Ashburn@soton.ac.uk
WWW http://www.sohp.ac.uk/sohp/

CONSENT FORM

Head postures and movements during activities in sitting, used by people following stroke. LREC NO 43/01/S

Name of Researcher: Kate Jupp **Patient Identification Number:**

Please tick the boxes as appropriate

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care being affected. ☐
3. I understand that sections of any of my medical notes may be looked at by the researcher and I give permission for the researcher to have access to my records. ☐
4. I agree to video recordings being taken of me during the study. ☐
5. I agree to take part in the above study. ☐
6. I agree to the videos being shown for educational purposes to medical audiences. ☐

____
Name of Patient

____________________ ____________________
Signature of patient Date

____________________ ____________________
Signature of researcher Date

Appendix IXd

Health and Rehabilitation Research Unit

Professor Ann Ashburn
PhD MPhil MCSP
Head of Unit

School of Health Professions and Rehabilitation Sciences

Professor R E Barnitt
PhD MSc FCOT
Head of School

Level E, Centre Block
(Mailpoint 886)
Southampton General Hospital
Tremona Road
Southampton
SO16 6YD
United Kingdom

Telephone +44 (0)23 8079 6469
Fax +44 (0)23 8079 4340
Email A.M.Ashburn@soton.ac.uk
WWW http://www.sohp.ac.uk/sohp/

CONSENT FORM

Head postures and movements during activities in sitting, used by people following stroke. LREC NO 24/02/S

Name of Researcher: Kate Jupp **Patient Identification Number:**

Please tick the boxes as appropriate

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care being affected. ☐
3. I understand that sections of any of my medical notes may be looked at by the researcher and I give permission for the researcher to have access to my records. ☐
4. I agree to video recordings being taken of me during the study. ☐
5. I agree to take part in the above study. ☐
6. I agree to the videos being shown for educational purposes to medical audiences. ☐

____
Name of Patient

____________________ ____________________
Signature of patient Date

____________________ ____________________
Signature of researcher Date

Appendix Xa

Abbreviated Mini- Mental Exam

Question	Score
How old are you?	
What time is it?	
Where do you live?	
Where do you live?	
Where are you?	
To identify 2 people	
What is your date of birth?	
In which year was the end of the 2nd world war?	
Who is the present monarch?	
To count backwards from 20 to 1	
	Total Score /10

Appendix Xb

Barthel ADL Index

	ADL	0	1	2	3	
1	Bowels	incontinent/ dependent	occasional accident	continent		
2	Bladder	incontinent/ catheterised	occasional accident	continent		
3	Grooming	needs help	independent			
4	Toilet use	dependent	needs some help	independent		
5	Feeding	unable	needs help	independent		
6	Transfer (bed to chair and back)	unable / no sitting balance	major help can sit	minor help	independent	
7	Mobility	immobile	w/ch independent	walks with one	independent	
8	Dressing	dependent	needs help	independent		
9	Stairs	unable	needs help	independent		
10	Bathing	dependent	independent			
					Total/20	

Appendix Xc

Rivermead Motor Assessment

	Gross function 1=can 0=cannot	Score 0/1
1	Sit unsupported (no hand or feet)	
2	Lying to sitting on side of bed	
3	Sit to stand (aid and hands permitted) in 15 seconds, for 15 seconds	
4	T/F chair to chair to unaffected side	
5	T/F chair to chair to affected side	
6	Walk 10m with aid (no standby help)	
7	Stairs (banister and aid)	
8	Walk 10m unaided	
9	Walk 10m pick up bean bag turn and return with aid (no help)	
10	Walk 40m outdoors may use aid	
11	Walk up and down 4 steps (no rail)	
12	Run 10m	
13	Hop on affected leg x5 without stopping	
	Gross function total/13	

	Leg and Trunk 1=can 0=cannot	Score 0/1
1	Roll to affected side (start flat)	
2	Roll to unaffected side	
3	Half-bridging (start in position)	
4	Sit to stand (no arms)	
5	Half crook-lying, lift affected leg over side of bed to box and return (must maintain knee flexion)	
6	Standing - step unaffected leg on and off block (without hip retraction and knee hyperextension)	
7	Standing – tap ground 5x with unaffected foot (as 6)	
8	Lying, dorsiflex affected ankle with flexed leg (can hold leg)	
9	Lying, dorsiflex affected ankle with extended leg (can hold leg)	
10	Stand and flex affected knee (keeping hip in neutral)	
	Leg and trunk total/10	

Arm 1=can 0=cannot		Score 0/1
1	Lying, protract shoulder girdle with arm in elevation (arm may be supported)	
2	Lying, hold extended arm in elevation with external rotation and no pronation (arm placed)	
3	Flexion/extension of arm in elevation (palm must not face out)	
4	Sitting elbow at side pronation and supination	
5	Reach forward and pick up large ball at arms length from table infront and return (palms on ball)	
6	Tennis ball table to affected side and return x5	
7	Pencil table to affected side and return x5	
8	Pick up piece of paper from table and release x5 (finger and thumb must not drag to edge of table)	
9	Cut putty into bite size pieces with knife and fork and place in container (can use non-slip mat)	
10	Stand on spot and bounce ball 5x with palm of hand	
11	Continuous opposition of thumb and each finger in sequence >14x in 15 seconds	
12	Pronation and supination of affected hand on unaffected palm >20x in 10 seconds	
13	Standing arm abducted to 90° with palm flat on wall at side. Turn to face wall and as far as possible to the arm (no elbow flexion)	
14	Place string around head and tie bow at back (no neck flexion)	
15	Pat-a-cake 7 x in 15 seconds (crosses on wall at shoulder level 2 crosses, clap, opposite cross, clap etc)	
	Arm total/15	

Appendix Xd

Berg Balance Scale

	Task	Score 0-4
1	Sit to stand	
2	Stand unsupported for 120 seconds	
3	Sit unsupported for 120 seconds	
4	Stand to sit	
5	Transfers	
6	Stand with eyes closed for10 seconds	
7	Stand with feet together for 60 seconds	
8	Reach forward with an outstretched arm	
9	Retrieve object from the ground	
10	Turn to look behind	
11	Turn 360 degrees	
12	Place alternate foot on stool	
13	Stand with one foot in front of the other for 30 seconds	
14	Stand on one foot for 10 seconds	
	Total score/56	

Appendix Xe

Mobility Milestones

	Subtest	Score Y/N
1	1-minute sitting balance (feet flat on floor arm resting on lap)	
2	10-second standing balance (= weight bearing, may have help to stand up)	
3	10 steps (no physical help)	
4	10-metre timed walk (can use aid)	

Appendix Xf

Nottingham Sensory Assessment

Body region	Light touch 0/1/2 0=absent 1= impaired 2= normal		Pressure 0=absent 1= impaired 2= normal	Kinaesthetic 0/1/2/3 0=absent 1= movement only 2= direction and movement 3= direction movement and end position sense		Score
	Right	Left		Right	Left	
Face						
Trunk						
Shoulder						
Elbow						
Wrist						
Hand						
Hip						
Knee						
Ankle						
Foot						
					Total score	

Appendix Xg

Behavioural Inattention Test

	Subtest	Score	
1	Line Crossing		/36
2	Letter cancellation		/40
3	Star cancellation		/54
4	Figure and shape copying from the left		/3
5	Line Bisection		/9
6	Representational drawing		/3
	Total score		/146

References

List of References

Adams, R. W., Gandevia, S. C., Skuse, N. F. (1990). The distribution of muscle weakness in upper motor neuron lesions affecting the lower limb. *Brain*, 113, 1459-76.

Ahlsen, E. (1991). Body communications as compensation for speech in a Wernicke's aphasic – a longitudinal study. *Journal of Communication Disorders*, 24, 1-12.

Allen, C. M. C. (1984). Predicting the outcome of acute stroke: a prognostic score. *Journal of Neurology, Neurosurgery & Psychiatry*, 47, 475-80.

Allum, J. H. J., Gresty, M., Keshner, E., Shupert, C. (1997). The control of head movements during human balance corrections. *Journal of Vestibular Research*, 7, 189-218.

Altorfer, A., Jossens, S., Wurmle, O., Kasermann, M. L., Foppa, K., Zimmermann, H. (2000). Measurement and meaning of head movements in everyday face to face communicative interaction. *Behaviour Research Methods, Instruments and Computers*, 32, 17-32.

Alund, M., Larsson, S. (1990). Three-dimensional analysis of neck motion a clinical method. *Spine*, 15, 87-91.

Altman, D. (1994). Practical Statistics for Medical Research. London: Chapman and Hall.

Aniansson, A., Hedberg, M., Henning, G. (1986). Muscle morphology enzymatic activity and muscle strength in elderly men: a follow-up study. *Muscle Nerve*, 9, 585-91.

Archambault, P., Pigeon, P., Feldman, A. G., Levin, M. F. (1999). Recruitment and sequencing of different degrees of freedom during pointing movements involving the trunk in healthy and hemiparetic subjects. *Experimental Brain Research*, 126, 55-67.

Ashburn, A. (1997). Atypical balance responses following stroke: A study of patients known as pushers. Dissertation (PhD), University of Southampton.

Ashburn, A., Veshuur, C., Rayner, S., Bailey, S. (2001). A Pilot investigation into the vestibular function of patients following stroke known as pushers and matched controls. Final Report: University of Southampton.

Ashburn, A., Partridge, C., Desouza, L. (1993). Physiotherapy in the rehabilitation of stroke: a review. *Clinical Rehabilitation*, 7, 337-45.

Assiante, C., Marchand, A. R., Amblard, B. (1989). Discrete visual samples may control locomotor equilibrium and foot positioning in man. *Journal of Motor Behaviour*, 21, 72-91.

Assiante, C., Amblard, B. (1993). Ontogenesis of head stabilisation in space during walking in children: influence of visual cues. *Experimental Brain Research*, 93, 499-513.

Balagura, S., Katz, R. G. (1980). Undecussated innervation to the sternocleidomastoid muscle: a reinstatement. *Annals of Neurology*, 7, 84-5.

Bamford, J., Sandercock, P., Warlow, C., Gray, M. (1986). Why are patients with acute stroke admitted to hospital? *British Medical Journal*, 292, 1369-1371.

Bamford, J., Sandercock, P., Dennis, M., Burn, J., Warlow, C., Jones, L. K., McPherson et al. (1988). A prospective study of acute cerebral vascular disease in the community: The Oxfordshire Community Stroke Project, 1. Methodology, demography and incident cases of first ever stroke. *Journal of Neurolology Neurosurgery and Psychiatry*, 51, 1373-80.

Bamford, J., Sandercock, P., Dennis, M., Burn, J., Warlow C. (1990). A prospective study of acute cerbrovascular disease in the community: 2. Incidence, case fatality rates and overall outcome at one year of cerebral infarction, primary intracerebral and subarachnoid haemorrhage. *Journal of Neurolology Neurosurgery and Psychiatry*, 53, 16-22.

Bamford, J., Sandercock, P., Dennis, M., Burn, J., Warlow C. (1991). Classification and natural history of clinically identifiable subtypes of cerebral infarction. *The Lancet*, 337, 1521-6.

Beevor, C. E. (1909). Paralysis of the movements of the trunk in hemiplegia. *British Medical Journal*, 1, 881-885.

Benaim, C., Perenou, D. A., Villy, J., Rousseaux, M., Pelissier, J. Y. (1999). Validation of a standardised assessment of postural control in stroke patients: the Postural Assessment Scale for Stroke Patients (PASS). *Stroke*, 30, 1862-8.

Bennett, B. (1996). How nurses in a stroke rehabilitation unit attempt to meet the psychological needs of patients who become depressed following a stroke. *Journal of Advanced Nursing*, 23, 314-21.

Bennett, S. E., Schenk, R. J., Simmons, E. D. (2002). Active range of motion utilized in the cervical spine to perform daily functional tasks. *Journal of Spinal Disorders and Techniques*, 15, 307-11.

Berg, K. (1989). Balance and its measure in the elderly: a review. *Physiotherapy Canada*, 41, 240-46.

Berg, K., Maki, B. E., Williams, J. I., Holliday, P. J., and Wood-Dauphinee, S. L. (1992). Clinical and laboratory measures of postural balance in an elderly population. *Archives of Physical Medicine and Rehabilitation*, 73, 1073-80.

Blonder, L. X., Burns, A. F., Bowers, D., Moore, R. W., Heilman, K. M. (1995). Spontaneous gestures following right hemisphere infarct. *Neuropsychologica*, 33, 203-213.

Bobath B. (1990). Adult Hemiplegia: Evaluation and treatment. 3rd edition. London: Heinemann Physiotherapy.

Bohannon, R., Smith, M., Lardin, P. (1986). Relationship between independent sitting balance and side of hemiparesis. *Physical Therapy*, 66, 944-5.

Bohannon, R. C. (1995). Recovery and correlates of trunk muscle strength after stroke. *International Journal of Rehabilitation Research*, 18, 262-7.

Bonita, R. (1992). Epidemiology of stroke. *The Lancet*, 339, 342-4.

Bonita, R., Solomon, N., Broad, J. B. (1997). Prevalence of stroke and stroke-related disability: Estimates from the Auckland Stroke Studies. *Stroke*, 28, 1899-1902.

Borod, J. C., Rorie, K. D., Haywood, C. S., Andelman, F., Obler, L. K., Welkowitz, J., Bloom, R. L., Tweedy, J. R. (1996). Hemisphere specialisation for disclosure reports of emotional experiences: relationships to demographic neurological and perceptual variables. *Neuropsychologica*, 34, 3251-9.

Brady, M., Mackenzie, C. (1999). Gesture use following right hemisphere brain damage. *Journal of Communication Disorders*, 2, 35-40.

Brennan, P. F., Hays, B. J. (1992). The kappa statistic for establishing inter-rater reliability in the secondary analysis of qualitative clinical data. *Research Nursing Health*, 15, 153-8.

Brennan, A., Silman, P. (1992). Statistical methods for assessing observer variability in clinical measures. *British Medical Journal*, 304 (6840), 1491-4.

Brill, B., Ledeby, A. (1998). Head coordination as a means to assist sensory integration in learning to walk. *Neuroscience Biobehavioural Review*, 22, 555-563.

Bronstein, A. M., Gresty, M. A. (1988). Short latency compensatory eye movement responses to transient linear head acceleration: a specific function of the otolith-ocular reflex. *Experimental Brain Research*, 71, 406-410.

Brown, L., Sleik, R., Winder, T. (2002). Attentional demands for static postural control after stroke. *Archives of Physical Medicine and Rehabilitation*, 83, 1732-5.

Brunnstrom, S. (1970). Movement therapy in hemiplegia. New York: Harper and Row.

Buchanan, J. J., Horak, F. B. (2001). Transitions in postural tasks: do the recruitment and suppression of degrees of freedom stabilise posture? *Experimental Brain Research,* 139, 482-494.

Burn, J., Sandercock, P. (1993). Predicting the outcome of acute stroke. *Journal of Neurology Neurosurgery and Psychiatry*, 53, 972-5.

Burnett, M. E. (2002). Comparartive analysis of Polaris and CODA marker systems. Dissertation (MSc), University of Surrey.

Butchalter, D., Parianpour, M., Viola, K., Nordin, M., Kahanovitz, N. (1989). Three dimensional spatial motion measurements. Part 1: a technique for examining posture and functional motion. *Journal of Spinal Disorders*, 1, 279-83.

Campbell, F. M. (1998). A description of dynamic reaching task in normal and hemiplegic subjects. Dissertation (MSc), University of Southampton.

Campbell, F. M., Ashburn, A., Pickering, R., Burnett, M. (2001). Head and Pelvic movements during a dynamic reaching task in sitting: implications for physical therapists. *Archives of Physical Medicine and Rehabilitation*, 82, 1655-60.

Capuano-Pucci, D., Rheault, W., Aukai, J., Brake, M., Day, R., Pastrick, M. (1991). Intra-tester and inter-tester reliability of the cervical range of motion device. *Archives of Physical Medicine and Rehabilitation*, 72, 338-40.

Carr, E. K., Kenney, F. D. (1994). Observing seated posture after stroke: a reliability study. *Clinical Rehabilitation*, 8, 329-333.

Carr, E. K., Kenney, F. D., Wilson-Barnett, J., Newham, D. J. (1999). Inter-rater reliability of postural observation after stroke. *Clinical rehabilitation*, 13, 229-242.

Carr, J. H., Shepherd, R. B. (1996). "Normal" is not the issue: It is "effective" goal attainment that counts. Commentary / Latash & Anson: Movements in atypical populations. *Behavioural and Brain Sciences*, 19, 55-106.

Carr, J. H., Shepherd, R. B., Gordon, J., Gentile, A. M., Held, J. M. (1987). Movement Science Foundations for Physical Therapy in Rehabilitation. London: Heinemann Physiotherapy.

Carr, J. H., Shepherd, R. B. (1987). A motor relearning programme for stroke. 2nd edition. London: Heinemann Physiotherapy

Catz, A., Rons, Solzi, P., Korcyzyn, A. D. (1994). The vestibular ocular reflex and disequilibrium after hemispheric stroke. *Amerian Journal of Physical Medicine and Rehabilitation*, 73, 36-39.

Chao, Y. E., Tanaka, S., Korinek, S. (1989). Measurement of neck range and pattern of movement. In Proceedings, International Congress of Biomechanics, Abstract #319. Los Angeles: University of California.

Chatterton, H. J., Pomery, V. M., Gratton J. (2001). Positioning for stroke patients: a survey of Physiotherapists' aims and practices. *Disability and Rehabilitation*, 23, 413-21.

Chen, J., Solinger, A. B., Poncet, J. F., Lantz, C. A. (1999). Meta-analysis of normative cervical motion. *Spine*, 24, 1571-1578.

Ching-Len, H., Ching-Fan, S., I-Ping, H., Chun-Hou, W. (2002). Trunk control as an early predictor of comprehensive activities of daily living function in stroke patients. *Stroke*, 33, 2626-30.

Chollet, F., Dipiero, V., Wise, R. J., Brooks, D. J., Dolan, R. J, Frackowiak, R. S. (1991). The functional anatomy of motor recovery after stroke in humans: a study with positron emission tomography. *Annals of Neurology*, 29, 63-71.

Cirstea, M. C., Levin, M. F. (2000). Compensatory strategies for reaching in stroke. *Brain*, 123, 940-953.

Clark, I. D., Opit, L. J. (1994). The prevalence of stroke in those at home and the need for care. *Journal of Public Health Medicine*, 16, 93- 6.

Cohen, J. (1968). Weighted Kappa: Nominal scale agreement with provision for scaled disagreement or partial credit. *Psychological Bulletin*, 70, 213-20.

Collin, C., Wade, D. (1990). Assessing motor impairment after stroke: a pilot reliability study. *Journal of Neurology Neurosurgery and Psychiatry*, 53, 576-9.

Conforto, A. B., Kaelin-Lang, A., Cohen, L. G. (2002). Increase in hand muscle strength of stroke patients after somatosensory stimulation. *Annals of Neurology*, 51, 122-5.

Conley, M. S., Meyer, R. A., Bloomberg, J. J., Feeback, D. L., Dudley, G. A. (1995). Non-invasive analysis of human neck muscle function. *Spine*, 20, 2505-2512.

Crane, B. T., Demer, J. L. (1997). Human gaze stabilisation during natural activities: translation, rotation, magnification, and target distance effects. *Journal of Neurophysiology*, 78, 2129-2144.

Cristea, M. C., Levin, M. F. (2000). Compensatory strategies for reaching in stroke. *Brain*, 123, 940-53.

Davidson, L., Waters, K. (2000). Physiotherapists working with stroke patients. *Physiotherapy*, 86, 69-80.

Davies, P. M. (1985). Steps to follow: A guide to the treatment of adult hemiplegia. Berlin: Springer-Verlag.

Davies, P. M. (1990). Right in the middle. Berlin: Springer-Verlag.

Davies, P. M. (1994). Starting Again. Berlin: Springer-Verlag.

Dean, C. M., Shepherd, R. B. (1997). Task related training improves performance of seated reaching tasks after CVA. A randomised control trial. *Stroke*, 28, 722-8.

De Gangi, G. A., Royeen, C. B. (1994). Current practice among neurodevelopmental treatment association members. *American Journal of Occupational Therapy*, 48, 803-9.

Denes, G., Semenza, C., Stoppa, E., Lis, A. (1982). Unilateral spatial neglect and recovery form hemiplegia. A follow up study. *Brain*, 105, 543-52.

Dennis, M., Warlow, C. (1987). Stroke: incidence, risk factors and outcome. *British Journal of Hospital Medecine*, March, 194-198.

Dennis, M. S., Burn, J. P. S., Sandercock, P. A. G., Bamford, J. M,, Wade, D. T., Warlow, C. P. (1993). Long term survival after first-ever stroke: the Oxfordshire community stroke project. *Stroke*, 24, 796-800.

Deitz, V., Quintern, J., Berger, W. (1981). Electrophysiological studies of gait in spasticity and rigidity: evidence that altered mechanical properties of muscle contribute to hypertonia. *Brain*, 104, 431-462.

Department of Health. (1992). Stroke rehabilitation: Does formal rehabilitation reduce disability and handicap and improve quality of life for people who suffered a stroke? *Effective Health Care Bulletin*, University of Leeds.

Department of Health. (2001). The expert patient: A new approach to chronic disease management in the 21st Century. London.

De Werdt, W., Selz, B., Nuyens, G., Staes, F., Swinnen, D., Van De Winckel, A., Nieuwboer, A., Lysens, R., Feys, H. (2000). Time use of stroke patients in an intensive rehabilitation setting: a comparison between a Belgian and Swiss setting. *Disability and Rehabilitation*, 22, 181-6.

De Seze, M., Wiart, L., Bon-Sint Comme, A., Debelleix, X., De Seze, M., Joseph, P., Mazaux, J., Barat, M. (2001). Rehabilitation of postural disturbances of hemiplegic patients by using trunk control retrainging during exploratory exercises. *Archives of Physical Medicine and Rehabilitation*, 82, 793-800.

Dickstein, R., Heffes, Y., Laufer, Y., Ben-Haim, Z. (1999). Activation of selected trunk muscles during symmetric functional activities in post-stroke hemiparetic and hemiplegic patients. *Journal of Neurology Neurosurgery and Psychiatry*, 66, 218-22.

Di Fabio, R. P., Badke, M. B., Duncan, P. W. (1986). Adapting human postural reflexes following localized cerebrovascular lesion: analysis of bilateral long latency responses. *Brain Research*, 363, 257-64.

Di Fabio, P. R., Emasithi, A. (1997). Ageing and the mechanisms underlying head movements and postural control during voluntary motion. *Physical Therapy*, 77, 458-74.

Dijkers, M. P., Kropp, G. C., Esper, R. M., Yavuzer, A., Cullen, N., Bakdalieh, Y. (2002). Reporting on reliability and validity of outcome measures in medical rehabilitation research. *Disability and Rehabilitation*, 24, 819-27.

Dombovy, M. L., Buton, A., Sandercock, P., Basford, J. R. (1986). Rehabilitation for stroke: A Review. *Stroke*, 17, 363-7.

Donoghue, J. P. (1995). Plasticity of adult sensorimotor representations. *Current Opinions in Neurobiology*, 5, 749-54.

Duncan, P. W., Weiner, D. K., Chandler, J., Studenski, S. (1990). Functional Reach: predictive validity in a sample of male veterans. *Journal of Gerontology*, 47, 93-98.

Duncan, P. W., Goldstein, L. B., Matchar, D., Divine, G. W., Feussner, J. (1992). Measurement of motor recovery after stroke: Outcome assessment and sample size. *Stroke*, 23, 1084-9.

Dvorak J, Hayek J, Zehnder R. (1987). CT-functional diagnostics of the rotatory instability of the upper spine Part 2 An evaluation on healthy adults and patients with suspected instability. *Spine*, 12, 726-731.

Dvorak, J., Panjabi, M. M., Loustalot, D., Bonomo, M. (1992). Age and gender related motion of the cervical spine. *Spine*, 17 (Suppl), S393-8.

Eccles, J. C. (1979). Synaptic plasticity. *Naturwissenschaften*, 66, 147-53.

Edwards, S. (1990). Neurological Physiotherapy. London: Churchill Livingstone.

Edwards, S. (1996). Neurological Physiotherapy: A problem solving approach. London: Churchill Livingstone.

Edwards, S. (2002) Neurological Physiotherapy. London: Churchill Livingstone.

Elveru, R. A., Rothstein, J. M., Lamb, R. L. (1988). Goniometric reliability in a clinical setting: Subtalar and ankle joint measurements. *Physical Therapy*, 68, 672-7.

Feigin, L., Sharon, B., Czaczkes, B., Rosin, A. J. (1996). Sitting equilibrium 2 weeks after stroke can predict the walking ability after 6 months. *Gerontology*, 42, 348-53.

Feinstein, A. R., Cicchetti, D. V. (1990). High agreement but low kappa: I. The problems of two paradoxes. *Journal of Clinical Epidemiology*, 43, 543-9.

Floel, A., Nagorsen, U., Werhahn, K. J. et al. (2004). Influence of somatosensory input on motor function in patients with chronic stroke. *Annals of Neurology*, 56, 206-212.

Forster, A., Young, J. (1992). Stroke rehabilitation. Can we do better? *British Medical Journal*, 305, 1446-7.

Forster, A., Young, J. (2002). The clinical and cost effectiveness of physiotherapy in the management of elderly people following a stroke: Evidence briefing. *The Chartered Society of Physiotherapy*, London.

Frank, J. S., Patla, A. E., Brown, J. E. (1987). Characteristics of postural control accompanying voluntary movement in the elderly. *Social Neuroscience Abstracts*, 13, 355.

Freidland, R. P., Weinstein, E. A. (1977). Hemi-inattention and hemispheric specialization: introduction and historical review. In: E. A., Weinstein, R. P. Freidland (Eds.). New York: Raven Press. *Advances in Neurology*, 18, 52-81.

Fries, W., Danek, A., Bauer, W. M., Witt, T. N., Leinsinger, G. (1990). Hemiplegia after lacunar stroke with pyramidal degeneration shown in vivo: a model for functional recovery. In: K. Von Wild, H. Janzik (Eds.). Neurologische Fruhrehabilitation. Munich: Zuchschwerd, 11-17.

Frithz, G., Werner, I. (1976). Studies on cerebrovascular strokes. II. Clinical findings and short term prognosis in a stroke material. *Acta Medical Scandinavia*, 199, 133-40.

Fullerton, K. J., MacKenzie, G., Stout, R. W. (1988). Prognostic indices in stroke. *Quarterly Journal of Medicine*, 66, 147-62.

Galski, T., Bruno, R. L., Zorowitz, R., Walker, J. (1993). Predicting length of stay, functional outcome, and aftercare in the rehabilitation of stroke patients. The dominant role of higher-order cognition. *Stroke*, 24, 1794-1800.

Garret, T. R., Youdas, J. W., Madson, T. J. (1993). Reliability of measuring forward head posture in a clinical setting. *Journal of Orthopaedic and Sports Physical Therapy*, 17, 155-60.

Geddes, J. M. L., Fear, J., Tennant, A., Pickering, A., Hillman, M., Chamberlain, M. A. (1993). Prevalance of self reported stroke in a population in northern England. *Journal of Epidemiology and Community Health*, 50, 140-143.

Gentile, A. M. (1987). Skill acquisition: action movement, and neuromotor processes. In: J. Carr, R. B. Shepherd (Eds.). Movement Science: Foundations for physical therapy in rehabilitation. Rockville: Aspen Systems.

Geschwind, N. (1981). Nature of the decussated inervation of the sterncleidomastoid muscle. *Annals of Neurology*, 10, 495.

Girardi, M., Konrad, H. R. (1998). Vestibular rehabilitation therapy for the patient with dizziness and balance disorders. *Head and Neck Nursing*, 16, 13-22.

Gladman, J. R. F., Harwood, D. M. J., Barer, D. H. (1992). Predicting the outcome of acute stroke: prospective evaluation of five multivariate models and comparison with simple models. *Journal of Neurology, Neurosurgery and Psychiatry*, 55, 347-51.

Goldpink, G., Williams, P. (1983). Muscle fibre and connective tissue changes associated with use and disuse. In: Key issues in Neurological physiotherapy. Ada and Canning (Eds). Oxford: Butterworth and Heineman.

Goodwin, C. (1986) Conversational organisation: interaction between speakers and hearers. New York: Academic Press.

Goossens, H. H. L. M., Van Opstal, A. J. (1997). Human eye-head coordination in two dimensions under different sensorimotor conditions. *Experimental Brain Research,* 114, 542-50.

Grossman. G. E., Leigh, R. J., Abel, L. A., Lanska, D. J., Thurston, S. E. (1988). Frequency and velocity of rotational head perturbations during locomotion. *Experimental Brain Research,* 70, 470-76.

Guion, R. M. (1977). Content validity: Three years of talk – what's the action? *Public Personnel Management*, 6, 407-14.

Guitton, D., Volle, M. (1987). Gaze control in humans : eye-head coordination during orienting movements to targets within and beyond the oculomotor range. *Journal of Neurophysiology,* 58, 427-59.

Hadar, U. (1991). Body movement during speech: Period analysis of upper arms and head movement. *Human Movement Science*, 10, 419-446.

Hadar, U., Steiner, T. J., Grant, E. C., Rose, F. C. (1983). Kinematics of head movement accompanying speech during conversation. *Human Movement Science*, 2, 35-46.

Hadar. U., Steiner, T. J., Grant, E. C., Rose, F. C. (1984). The timing and shifts of head postures during conversation. *Human Movement Science*, 3, 237-245.

Hammond R, Lennon S on behalf of the Intercollegiate Working Party for Stroke (2002) Physiotherapy Specific Guidelines for Stroke. Chartered Society for Physiotherapy and Royal College of Physicians, London.

Hansen, P. D., Woollacott, M. H., Debu, B. (1988). Postural responses to changing task conditions. *Experimental Brain Research,* 73, 627-36.

Hanten, W. P., Olson, S. L., Russell, J. L., Lucio, R. M., Campbell, A. H. (2001). Total head excursion and resting head posture: normal and patient comparisons. *Archives of Physical Medicine and Rehabilitation*, 81, 62-6.

Harms, M. (1990). Effect of Wheel chair design on Posture and Comfort of Users. *Physiotherapy*, 76, 266-271.

Heath, C. (1986). Talk and recipiency: Sequential organisation of speech and body movement. In: Structures of Social action. J. M. Atkinson, J. Heritage (Eds.). Cambridge: Cambridge University Press, 247-265.

Heilman, K. M., Valenstein, E. (1979). Mechanisms underlying hemispatial neglect. *Annals of Neurology*, 5, 166-70.

Herdman, S. J. (1994). Vestibular Rehabilitation. Philadelphia: F. A. Davis Co.

Hirschfeld, H., Forssberg, H. (1992). Development of anticipatory postural adjustments during locomotion in children. *Journal of Neurophysiology*, 68, 542-50.

Hodkinson, H. M. (1972). Evaluation of a mental test score for assessment of mental impairment in the elderly. *Age and Ageing*, 1, 233-8.

Horak, F. B. (1987). Clinical measurement of postural control in adults. *Physical Therapy*, 67, 1881-5.

Horak, F. B., Esselman, P., Anderson, M. E., Lynch, M. K. (1984). The effects of movement velocity, mass displaced, and task certainty on associated postural adjustments made by normal and hemiplegic individuals. *Journal of Neurolog,y Neurosurgery and Psychiatry*, 47, 1020-28.

Horak, F. B., Diener, H. C., Nashner, L. M. (1989). Influence of central set on human postural responses. *Journal of Nerophysiology*, 62, 841-53.

Horak, F. B., Diener, H. C. (1994). Cerebellar control of postural scaling and centrals set. *Journal of Neurophysiology*, 72, 479-93.

Houx, P., Jolles, J. (1993). Age related decline of psychomotor speed: effects of age, brain health, sex and education. *Perception and Motor Skills*, 76, 195-211.

Huxham. F. E., Goldie, P. A., Patla, A. E. (2001). Theoretical considerations in balance assessment. *Australian Journal of Physiotherapy*, 47, 89-100.

Hyndman, D., Ashburn, A. (2002). People with stroke living in the community: An investigation into the relationship between attention, balance and falls. *Clinical Rehabilitation*, 16, 228-32.

Hyndman, D. (2002). Falls Experienced by People with Stroke Living in the community. Dissertation (PhD), University of Southampton.

Inglin, B., Woolacott, M. (1988). Age related changes in anticipatory postural adjustments associated with arm movements. *Journal of Gerontological Medical Science*, 43, M105-13.

Inglis, J. T., Horak, F. B., Shupert, C. L., Jones-Rcewicz, C. (1994). The importance of somatosensory information in triggering and scaling automatic postural responses in humans. *Experimental Brain Research*, 101, 159-64.

Intercollegiate Working Party for Stroke (2004) National Clinical Guidelines for Stroke. Royal College of Physicians, London.

Jackson, J. (1994). Approaches to neurological rehabilitation by physiotherapists. *British Journal of Therapy and Rehabilitation*, 1, 71-4.

Johnston, M. (1987). Restoration of motor function in the stroke patient: A physiotherapist's approach. Edinburgh: Churchill and Livingstone.

Johnston, M., Morrison, V., MacWalter, R., Partridge, C. (1999). Perceived control, coping and recovery from disability following stroke. *Psychology and Health*, 14, 181-92.

Jongbloed, L. (1986). Prediction of function after stroke: A critical review. *Stroke*, 17, 765-76.

Kalra, L., Evans, A., Perez, I., Knapp, M., et al. (2000). Alternative strategies for stroke care: a prospective randomised controlled trial. *The Lancet*, 356, 894-9.

Karnath, H. O., Ferber, S., Dichgans, J. (2000). The origin of contraversive pushing, evidence for a second graviceptive system in humans. *Neurology*, 55, 1298-1304.

Kelso, J. A. S., Buchanan, J. J., Deguzman, G. C., Ding, M. (1993). Spontaneous recruitment and anihilation of degrees of freedom in biological coordination. *Physiology Letters*, 179, 364-71.

Kendon, A. (1990). Conducting interaction: Patterns of behaviour in focused encounters. Cambridge: Cambridge University Press.

Keshner, E. A., Peterson, B. W. (1995) Multiple control mechanisms contribute to functional behaviours of the head and neck. In: The head and neck sensory motor system. A. Berthoz, W. Graf,P. Vidal (Eds.). Oxford: Oxford University Press.

Kinsella, G., Ford, B. (1980). Acute recovery patterns in stroke patients. Neuropsychological factors. *Medical Journal of Australia*, 2, 663-6.

Kinsella G, Oliver J, Ng K, Packer S, Stark R. (1993). Analysis of the syndrome of unilateral neglect. *Cortex*, 29, 135-40.

Knott, M., Voss, D. (1969). Proprioceptive neuromuscular facilitation patterns and techniques. 2nd ed. London: Butterworths.

Konczak, J., Dichgans, J. (1996). The concept of "normal" movement and its consequences for therapy. Commentary / Latash & Anson: Movements in atypical populations. *Behavioural and Brain Sciences*, 19, 55-106.

Konrad, H. R. (1991). Clinical application of saccade-reflex testing in Man. *Laryngoscope*, 101, 1293-1302.

Konrad, H. R., Giradi, M., Helfert, R. (1999). Balance and Ageing. *Laryngoscope*, 109, 1454-60.

Krebs. D. E., Gill-Body, K. M., Parker, S. W., Ramirez, J. V., Wernick-Robinson, M. (2003). Vestibular rehabilitation: Useful but not universally so. *Otolaryngol Head and Neck Surgery*, 128, 240-50.

Kuhlman, K. A. (1993). Cervical range of motion in the elderly. *Archives of Physical Medicine and Rehabilitation*, 74, 1071-9.

Kwakkel, G., Waagenaar, R. C., Kollen, B. J. (1996). Predicting disability in stroke – a critical review of the literature. *Age and Ageing*, 25, 479-89.

Kwakkel, G., Waagenaar, R. C., Twisk, J. W., Lankhors, G. J., Koestier, J. C. (1999). Intensity of leg and arm training after primary and middle-cerebral artery stroke: a randomised controlled trial. *Lancet*, 354, 191-196.

Kwackel, G., Wagenaar, R. C. (2002). Effects of duration of upper- and lower-extremity rehabilitation sessions and walking speed on recovery of interlimb coordination in hemiplegic gait. *Physical Ther*apy, 82, 432-48.

Kwakkel, G., Van Peppen, R. P. S., Waagenaar, R. C. (2004). Effects of augmented exercise therapy time after stroke. *Stroke*, 35, 2529-39.

Lamontagne, A., Paquet, N., Fung, J. (2003). Postural adjustments to voluntary head motions during standing are modified following stroke. *Clinical Biomechanics*, 18, 832-42.

Lamontagne, A., Kairy, D., Paquet, N., Fung, J. (2001). Postural adjustments to voluntary head turns during walking in stroke subjects. In: Control of Posture and Gait. J. Duysens, B. C. M. Smits-Engelsman, H. Kingma (Eds.). 660-665.

Landis, J. R., Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 33, 159-73.

Langhorne, P., Wagenaar, R., Partridge, C. (1996). Physiotherapy after stroke: more is better? *Physiotherapy Research International*, 77, 559-53.

Langhorne, P., Denni, M., Kalra, L., Shepperd, S. et al. (2004). Services for helping acute stroke patients avoid hospital admission (Cochrane Review). In: The Cochrane Library, Issue 1. Chichester: John Wiley and Sons.

Lanzetta, D., Cattaneo, D., Pellegatta, D., Cardini, R. (2004). Trunk control in unstable sitting posture during functional activities in healthy subjects and patients with Multiple Sclerosis. *Archives of Physical Medicine and Rehabilitation*, 85, 279-83.

Latash, M. L., Anson, J. G. (1996). What are "normal movements" in atypical populations? *Behavioural and Brain Sciences*, 19, 55-106.

Le May, A., David, R., Thomas, A. P. (1988). The use of spontaneous gesture by aphasic patients. *Aphasiology*, 2, 137-45.

Lennon, S. (2000). Gait re-education based on the Bobath Concept in adult patients with hemiplegia following stroke. Dissertation (PhD). Northern Ireland: University of Ulster at Jordanstown.

Lennon, S. (2001). Gait re-education based on the Bobath Concept in two patients with hemiplegia following stroke. *Physical Therapy*, 81, 924-34.

Lennon, S. (2003). Physiotherapy practice in stroke rehabilitation: a survey. *Disability and Rehabilitation*, 25, 455-461.

Lennon, S., Ashburn, A. (2000). The Bobath concept in stroke rehabilitation: a focus group design of the experienced physiotherapists' perspective. *Disability and Rehabilitation*, 22, 665-74.

Levin, M. F. (1996). Should stereotypic movements synergies in hemiparetic patients be considered adaptive? Commentary / Latash & Anson: Movements in atypical populations. *Behavioural and Brain Sciences*, 19, 55-106.

Levin, M. F., Michaelsen, S. M., Cirstea, C. M., Roby-Brami, A. (2002). Use of the trunk for reaching targets placed within and beyond the reach in adult hemiparesis. *Experimental Brain Research*, 142, 171-80.

Lincoln, N., Leadbitter, D. (1979). Assessment of motor function in stroke patients. *Physiotherapy*, 65, 48-51.

Lincoln, N. B., Jackson, J. M., Adams, S. A. (1998). Reliability and revision of the Nottingham Sensory Assessment for stroke patients. *Physiotherapy*, 84, 358-65.

Lincoln, N. B., Jackson, J. M., Edmans, J. A. (1990). The accuracy of predictions about progress of patients on a stroke unit. *Journal of Neurology Neurosurgery and Psychiatry*, 53, 972-5.

Lindgren, A., Norrving, B., Rudling, O., Johansson, B. B. (1994). Comparison of clinical and neuroradiological findings in first ever stroke: a population-based study. *Stroke*, 25, 1371-77.

Lofgren, B., Nyberg, L., Osterlind, P. O., Gustafson, Y. (1998). In-patient rehabilitation after stroke: outcome and factors associated with improvement. *Disability and Rehabilitation*, 20, 55-61.

Lord, S, R., Clark, R. D., Webster, I. W. (1991). Visual acuity and contrast sensitivity in relation to falls in an elderly population. *Age and Ageing*, 20, 175-81.

Lowen, S. C., Anderson, B. A. (1990). Predictors of stroke outcome using objective measurement scales. *Stroke*, 21, 78-81.

Lynch, M., Grisogno, V. (1991). Strokes and Head Injuries. London: John Murray.

Ma, S., Feldman, A. G. (1995). Two functionally different synergies during arm reaching movements involving the trunk. *Journal of Neurophysioogy*, 73, 2120-2.

Mahoney, F. I., Barthel, D. W. (1965). Functional evaluation: The Barthel Index. *Maryland State Medical Journal*, 14, 61-5.

Maki, B. E., McIlroy, W. E. (1997). The role of limb movements in maintaining upright stance: the 'change-in-support' strategy. *Physical Therapy*, 77, 488-507.

Maki, BE., Whitelaw, R. S. (1993). Influence of expectation and arousal on centre-of-pressure responses to transient postural perturbations. *Journal of Vestibular Research*, 3, 25-39.

Malouin, F., Prefontaine, J., Richards, C. L. (1989). Quantitative evaluation of head posture and movements with a triaxial electrogoniometer; a reproducibility study. *Physiotherapy Canada*, 41, 294-301.

Mant, J., Wade, D., Winner, S. H. (2004) Health care needs assessment stroke. In: Health care needs assessment: the epidemiologically based needs assessment reviews. 2nd edition. A. Stevens, J. Raferty, J. Mant, S. Simpson (Eds.). Oxford: Radcliffe Medical Press.

Marchand, A. R., Amblard, B. (1984). Locomotion in adult cats with early vestibular deprivation: visual cue substitution. *Experimental Brain Research,* 54, 395-405.

Marchand, A. R., Amblard, B., Cremieux, J. (1988). Visual and vestibular control of locomotion in early and late sensory-deprived cats. *Progressive Brain Research,* 76, 229-38.

Massion, J. (1984). Postural changes accompanying voluntary movements. Normal pathological aspects. *Human Neurobiology*, 2, 261-7.

Massion, J., Woollacott, M. H. Posture and equilibrium. In: Clinical disorders of balance posture and gait. New York: DeGruyter.

Mastaglia, F. L., Knevevic, W., Thompson, P. D. (1986). Weakness of head turning in hemiplegia: a Quantitative study. *Journal of Neurology, Neurosurgery, and Psychiatry*, 49, 195-7.

Maurer, C., Mergner, T., Bolha, B., Hlavacka, F. (2000). Vestibular, visual, and somatosensory contributions to human control of upright stance. *Neuroscience Lett*ers, 281, 99-102.

Mayston, M. (2000). Handling and spasticity (letter to the editor). *Physiotherapy*, 86, 559.

McCloskey, D. I. (1978). Kinaesthetic sensibility. *Physiological reviews*, 58, 763-820.

McDonald, P. V., Bloomberg, J. J., Basdogan, C., Layne, C. S. (1997). Lowe limb kinetics during treadmill walking after space flight: Implications for gaze stabilisation. *Experimental Brain Research*. 112, 325-334.

McNeil, D. (1992). Hand and mind. Chicago: The University of Chicago Press.

Medendorp, W. P., Melis, B. J., Gielen, C. C., Van Gisbergen, J. A. (1998). Off-centric rotation axes in natural head movements: Implications for vestibular reafference and kinematic redundancy. *Journal of Neurophysiology*, 79, 2025-39

Messier, S., Bourbonnais, D., Desrosiers, J., Roy, Y. (2004). Dynamic analysis of trunk flexion after stroke. *Archives of Physical Medicine and Rehabilitation*, 85, 1619-24.

Michaelsen, S. M., Luta, A., Roby-Brami, A., Levin, M. F. (2001). Effect of trunk restraint on the recovery of reaching movement in hemiparetic patients. *Stroke*, 32, 1875-91.

Mimura, A., Mmoriya, A., Watanabe, T. (1989). Three dimensional motion analysis of the cervical spine with special reference to the axial rotation. *Spine*, 14, 1135-1139.

Morgan, P. (1994). The relationship between sitting balance and mobility outcome in stroke. *Australian Journal of Physiotherapy*, 40, 91-6.

Mudie, M. H., Winzeler-Mercay, U., Radwan, S., Lee L. (2002). Training symmetry of weight distribution after stroke: a randomised controlled pilot study comparing task-related reach, Bobath, and feedback training approaches. *Clinical Rehabilitation*, 16, 582-92.

Mulavara, A. P., Verstraete, M. C., Bloomberg, J. J. (2002). Modulation of head movement control in humans during treadmill training. *Gait and Posture*, 16, 271-82.

National Service Framework for Older People Department of Health (2001). Standard Five: Stroke: 61.

Nashner, L. M. (1985). Strategies for organisation of human posture. In: Vestibular and visual control on posture and locomotion. Igarashi and Black (Eds.). Houston: Karger and Basel.

Nieuwboer, A., Feys, H., De Weerdt, W., Nuyens, G., De Corte, E. (1995). Developing a clinical tool to measure sitting balance after stroke: a reliability study. *Physiotherapy*, 81, 439-45.

Nudo, R. J., Plautz, E. J., Milliken, G. W. (1997). Adaptive plasticity in primate motor cortex as a consequence of behavioural experience and neuronal injury. *Seminar in the Neurosciences*, 9, 13-23.

Office of National Statistics (1998). Series DH 2 No 24. Mortality statistics causes. England and Wales 1997 (London: HMSO) .

Palmer, E., Downes, L., Ashby, P. (1996). Associated postural adjustments are impaired by lesions of the cortex. *Neurology*, 46, 471-5.

Parry, R. H., Lincoln, N. B., Vass, C. D. (1999). Effects of severity of arm impairment on response to additional physiotherapy early after stroke. *Clinical Rehabilitation*, 13, 187-198.

Partridge, C. J., Johnston, M., Edwards, M. S. (1987). Recovery from physical disability after stroke: normal patterns as a basis for evaluation. *The Lancet*, 1, 373-5.

Partridge, C. J., Morris, L. W., Edwards, M. S. (1993). Recovery from physical disability after stroke: Clinical Rehabilitation, 39, 281-89.

Paulus, W. M., Straube, A., Brandt, T. (1984). Visual stabilisation of posture: Physiological stimulus characteristics and clinical aspects. *Brain*, 107, 1143-63.

Pedderson, P. M., Wandel, A., Jorgensen, H. S, Nakayama, J., Raaschou, H. O., Olsen, T. S. (1996). Ipsilateral pushing in stroke: Incidence, relation to neuropsychological symptoms and impact on rehabilitation. The Copenhagen stroke study. *Archives of Physical Medicine and Rehabilitation*, 77, 25-28.

Pelz, J., Hayhoe, M., Loeber, R. (2001). The coordination of eye, head, and hand movements in a natural task. *Experimental Brain Research*, 139, 266-77.

Penning, L., Wilmink, J. T. (1987). Rotation of the cervical spine. A CT study in normal subjects. *Spine*, 12, 726-731.

Perennou, D., Bronstein, A. (2004). Verticality misrepresentation and postural disorders in stroke patients. *Journal of Vestibular Research*, 14, 161-162.

Pettersen, B. W., Choi, W., Hain, T., Keshner, E., Peng, G. (2001). Dynamic and kinetic strategies for head movement control. *Annals of the New York Academy of Science*, 942, 381-393.

Pollock, A., Baer, G., Pomeroy, V., Langhorne, P. (2004). Physiotherapy treatment approaches for the recovery of postural control and lower limb function following stroke. *The Cochrane Library*, Issue 2.

Pollock, A. S., Durward, B. R., Rowe, P. J., Paul, P. J. (2000). What is balance? *Clinical Rehabilitation*, 14, 402-06.

Pomeroy, V. M., Tallis, R. C. (2002). Restoring movement and functional ability after stroke: now and the future. *Physiotherapy*, 88, 3-17.

Pozzo, T., Berthoz, A., Lefort, L. (1990). Head stabilisation during various locomotor tasks in humans I. Normal subjects. *Experimental Brain Research,* 82, 97-106.

Pozzo, T., Berthoz, A., Lefort, L., Vitte, E. (1991). Head stabilisation during various locomotor tasks in Humans I. Normal Subjects. *Experimental Brain Research*, 82, 97-106.

Prescott, R. J., Garraway, W. M., Akhtar, A. J. (1982). Predicting functional outcome following acute stroke using standard clinical examination. *Stroke*, 13, 641-7.

Prudham, D., Evans, J. G. (1986). Factors associated with falling in the elderly: a community study. *Age and Ageing*, 10, 141-6.

Raisman, G., Field, P. M. (1973). A quantitative investigation of the development of collateral reinnervation of the septal nuclei after partial deafferentation. *Brain Research*, 50, 241-64.

Richards, C. L., Malouin, F., Wood-Dauphinee, S., Williams, J. I., Bouchard, J., Brunet, D. (1993). Task specific physiotherapy for optimisation of gait recovery in acute stroke patients. *Archives of Physical Medicine and Rehabilitation*, 74, 612-20.

Richter, E. (1980). Quantitative study of human Scarpas ganglion and vestibular sensor epithelia. *Acta Otoalaryngol*, 90, 199-208.

Roberts, T. D. M. (1976). The role of the vestibular and neck receptors in locomotion. In: Neural control of locomotion. R. M. Herdman, S. Grillner, P. S. G. Stein, D. G. Stuart (Eds). New York: Plenum.

Robertson, I. H., Ridgeway, V., Greenfield, E., Parr, A. (1997). Motor recovery after stroke depends on intact sustained attention: A 2-year follow up study. *Neuropsychology*, 11, 290-5.

Robinson, J. D. (1998). Getting down to business: Talk, gaze and body orientation during openings of Doctor-patient consultations. *Health Communication*, 25, 97-123.

Roby-Brami, A., Fuchs, S., Mokhtari, M., Bussel, B. (1997). Reaching and grasping strategies in hemiparetic patients. *Motor Control*, 1, 72-91.

Rosenhall, U. (1973). Degenerative patterns in the aging human vestibular neuro-epithelia. *Acta Otolaryngol*, 76, 208-20.

Rudd, A. G., Irwin, P., Rutledge, Z., Lowe, D., Morris, R., Pearson, M. G. (1999). The National sentinel audit of stroke: a tool for raising standards of care. *Journal of the Royal College of Physicians*, 30, 460- 4.

Sackley, C. M., Lincon, N. B. (1996). Physiotherapy treatment for stroke: a survey of current practise. *Physiotherapy Theory and Practise*, 12, 87-96.

Sandin, K. J., Smith, B. J. (1990). The measure of balance in sitting in stroke rehabilitation. *Stroke*, 21, 82-86.

Schegloff, E. A. (1997). The preference for self-correction in the organisation of repair in conversation. *Language*, 53, 361-82.

Schmidt, R. A. (1988). Motor control and learning. A behavioural emphasis. 2nd edition. Champaign, IL: Human Kinetics Publishers.

Shahar, E., McGovern, P. G., Sprafka, J. M., Pankow, J. S., Doliszny, K. M., Leuker, R. V., Blackburn, H. (1995). Improved survival of stroke patients during the 1980s. The Minnesota Stroke Survey. *Stroke*, 26, 1-6.

Shephard, N. T,, Telian, S. A. (1996). Practical management of the balance disorder patient. San Diego: Singular Publishing Group, 85-108.

Shumway-Cook, A. (1996). Critical analysis of measurement in balance: a clinical approach. In: Proceedings of the 16th American Physical Therapy Association, Combined Sciences Meeting. (Feb 1996). Atlanta: American Physical Therapy Association, 5-8.

Shumway-Cook, A., Woolacott, M. (1995). Motor Control: Theory and Practical applications. Baltimore: Williams and Wilkins.

Sinclair, R. (1995). A study examining dynamic sitting balance and the presence of attention deficit post stroke. Dissertation (MSc), University of Southampton.

Skilbeck, C. E., Wade, D. T., Langton-Hewer, R., Wood, V. A. (1983). Recovery after stroke. *Journal of Neurology, Neurosurgery, and Psychiatry*, 46, 5-8.

Smith, M. T., Baer, G. T. (1999). Achievement of simple mobility milestones after stroke. *Archives of Physical Medicine and Rehabilitation*, 80, 442-447.

Smith, J., Brotheridge, S., Young, J. (2001). Patterns of hemiparesis recovery in lacunar and partial anterior circulation infarct stroke syndromes. *Clinical Rehabilitation*, 15, 59-66.

Sodhi, R. S. (2000). Evaluation of head and neck motion with the hemispherical shell method. International *Journal of Industrial Ergonomics*, 25, 683-91

Stack, E. (2002). Movements used during turning and factors influencing the way in which people with Parkinson's Disease turn. Dissertation (PhD), University of Southampton.

Stephen, A., Rafferty, J. (Eds.) (1994). Health Care Needs Assessment 1994. Volume 1. Oxford: Radcliffe Medical Press.

Stillman, B. C. (2002). Making sense of proprioception: The meaning of proprioception, kinaesthesia and related terms. *Physiotherapy*, 88, 667-676.

Stone, S. P., Wilson, B., Wroot, A., Halligan, P. W., Lange, L. S., Marshall, J. C., Greenwood, R. J. (1991). The assessment of visuo-spatial neglect after acute stroke. *Journal of Neurology, Neurosurgery and Psychiatry*, 54, 345-50.

Stone, S. P., Halligan, P. J., Greenwood, R. J. (1993). The incidence of neglect phenomenon and related disorders in patients with an acute right or left hemispherical stroke. *Age and Ageing*, 22, 46-52.

Streiner, D. L., Norman, G. R. (2000). Health Measurement Scales: A Practical Guide To Their Development And Use. UK: Oxford Medical Publications.

Stroke Units' Trialists Collaboration (2000). Organised inpatient (Stroke Unit) care for stroke. *Cochrane Database of Systematic Reviews*, 2.

Stroke Units' Trialists Collaboration (2004). Organised inpatient (Stroke Unit) care for stroke. (Cochrane Review). In: The Cochrane Library, Issue 1, 2004. Chichester: John Wiley and Sons.

Tanaka, S., Hachisuka, K., Ogata, H. (1997). Trunk rotatory muscle performance in post-stroke hemiplegic patients. *American Journal of Physical Medicine and Rehabilitation,* 76, 366-9.

Taylor, D., Ashburn, A., Ward, C. D. (1994). Asymmetrical trunk posture, unilateral neglect and motor performance following stroke. *Clinical Rehabilitation*, 8, 48-53.

Terent, A. (1993). Costs of stroke care. Lower costs in spite of increased incidence. *Lakartidningen*, 90, 2758-63.

Thielman, G. T., Dean, C. M., Gentile, A. M. (2004). Rehabilitation of reaching after stroke: task-related training versus progressive resistive exercise. *Archives of Physical Medicine and Rehabilitation,* 85, 1613-8.

Thorndike, E. L. (1920). A constant error in psychological ratings. *Journal of Applied Psychology*, 4, 25-29.

Thorvaldsen, P., Kuulasmaa, K., Rajakangas, A. M., Rastenyte, D., Sarti, C., Wilhelmsen, L. (1997). Stroke trends in the WHO MONICA Project. *Stroke*, 28, 500-506.

Trombly, C. A., Wu, C. Y. (1999). Effects of rehabilitation tasks on organisation of movement after stroke. *American Journal of Occupational Therapy*, 53, 333-44.

Tsur, A., Solzi, P. (1996). Cervical spine movements in hemiparetic patients. *Brain Injury*, 10, 697-701.

Tyson, S. F., Desouza, L. H. (2003). A clinical model for the assessment of posture and balance in people with stroke. *Disability and Rehabilitation*, 25, 120-6.

Van Peppen, R. P. S., Kwackel, G., Wood-Dauphinee, S., Hendricks, H. J. M., Van der Wees, P. H. J., Decker, J. (2004). The impact of physical therapy on functional outcomes after stroke: what's the evidence? *Clinical Rehabilitation*, 18, 833-62.

Verhayden, G., Nieuwboer, A., Mertin, J., Kiekens, C., De Weert, W. (2004). Trunk Impairment Scale: a new tool to measure motor impairment of the trunk after stroke. *Clinical Rehabilitation*, 18, 326-34.

Wade, D. T., Skillbeck, C. E., Langton-Hewer, R. (1983). Predicting Barthel ADL score at six months after an acute stroke. *Archives of Physical Medicine and Rehabilitation*, 64, 24-8.

Wade, D. T., Skilbeck, C. E., Langton-Hewer, R., Wood, V. A. (1984). Therapy after stroke: amounts, determiniants and effects. *International Rehabilitation Medicine,* 6, 105-10.

Wade, D., Wood, V., Langton-Hewer, R. (1985). Recovery after stroke: The first three months. *Journal of Neurology, Neurosurgery and Psychiatry*, 48, 7-13.

Wade, D. T, Hewer, R. L. (1987). Functional abilities after stroke: measurement, natural history and prognosis. *Journal of Neurology, Neurosurgery and Psychiatry*, 50, 177-82.

Wade, M. G., Jones, G. (1997). The role of vision and spatial orientation in the maintenance of posture. *Physical Therapy*, 77, 619-27.

Wade, D. (1998). Evidence relating to assessment in rehabilitation. *Clinical Rehabilitation*, 12, 115-8.

Wade, D. (2003). Selection criteria for rehabilitation services. *Clinical Rehabilitation*, 17, 183-6.

Walbott, H. G. (1995). Analysis of nonverbal communication. In: Aspects of Oral Communication. U. M. Quasthoff (Ed.). New York: DeGruyter.

Walmsey, R. P., Kimber, P., Culham, E. (1996). The effect of initial head position on active cervical axial rotation range of motion in two age populations. *Spine*, 21, 2435-442.

Ward, N. S., Cohen, L. G. (2004). Mechanisms underlying recovery of motor function after stroke. *Archives of Neurology*, 61, 1844-48.

Warlow, C. (2001). Disorders of the cerebral circulation. In: Diseases of the nervous system. J. Walton (Ed.). Oxford: Oxford University Press.

Webb Associates (1978). Anthropometric Source Book. Vol. I, NASA 1024. Washington, D.C: National Aeronautics and Space Administration.

Weiller, C., Chollet, F., Friston, K. J., Wis, R. J., Frackowiak, R. S. (1992). Functional reorganisation of the brain in recovery from striatocapsular infarction in man. *Annals of Neurology,* 33, 181-9.

Welch, G., Bishop, G., Viccil, S., Brumback, S., Keller, K., Collucci, D. (1999). Hiball Tracker: High performance wide-area tracking for virtual and augmented environments. Symposium on Virtual Reality Software and Technology. University College London.

Werhahn, K. J., Mortensen, J., Van Boven, R. W., Zeuner, K. E., Cohen, L. G. (2002). Enhanced tactile special acuity and cortical processing during acute and deafferentation. *Nature and Neuroscience*, 5, 936-8.

Wernick-Robinson, M., Krebs, D. E., Giorgetti, M. M. (1999). Functional reach: Does it really measure dynamic balance? *Archives of Physical Medicine*, 80, 262-9.

Wertz, R. T., Henschel, C. R., Fluther, L. L., Ashford, J. R., Kirshner, H. S. (1998). Affective prosodic disturbance subsequent to right hemisphere stroke: a clinical application. In: Pragmatics in Neurogenic Communication disorders. M. Paradis (Ed.) Oxford: Pergamon, Elsevier Science.

Whipple, R. H., Wofson, L. I., Amerman, P. M. (1987). The relationship of knee and ankle weakness to falls in nursing home residents: an isokinetic study. *Journal of the American Geriatric Society*, 35, 13-20.

Whipple R, Wofson L, Derby C, Singh J, Tobin J. (1993). Altered sensory function and balance in older persons. *Journal of Gereontology,* 48, 71-76.

Whitney, S. L., Wrisley, D. M., Marchetti, G. F., Furman, J. M. (2002). The effect of age on vestibular rehabilitation outcomes. *Laryngoscope*, 112 (10), 1785-90.

Wiesendanger, M. (1990). Weakness and the upper motor neurone syndrome: a critical pathophysiological appraisal. In: Motor disturbances II. A. Beradelli, R. Benecke, M. Manfredi, C. D. Marsden (Eds.). London: Academic Press. 319-31.

Wilkinson, P. R., Wolfe, C. D. A., Warburton, F. G., Rudd, A. G., Howard, R. S., Ross-Russell, A., Beech, R. R. (1997). A long-term follow-up of stroke patients. *Stroke,* 28 (3), 507-512.

Willoughby, E. W., Anderson, N. E. (1984). Lower cranial nerve motor function in uni-lateral vascular lesions of the cerebral hemisphere. *British Medical Journal*, 298, 791-4.

Wilson, B., Cockburn, J., Halligan, P. (1987). The Behavioural Inattention Test. Tichfield: Thames Valley Test Company.

Winter, D. A. (1990). Biomechanics and Motor Control of Human Movement. 2nd ed. New York: John Wiley & Sons Inc.

Winter, D. A. (1995). Human Balance and Postural Control during Standing and Walking. *Gait and Posture,* 3, 193-214.

Wolfe, C., Rudd, A., Howard, R., Coshall, C., et al. (2002). Incidence and case fatality rates of stroke subtypes in a multiethnic population: the South London stroke register. *Journal of Neurology, Neurosurgery and Psychiatry*, 74, 211-6.

Woollacott, M. H., Shumway-Cook A., Nashner, L. M. (1986). Aging and posture control: Changes in sensory organisation and muscular coordination. *International Journal of Aging and Human Development*, 23, 97-114.

Woldag, H., Hummelsheim, H. (2002). Evidence-based physiotherapeutic concepts for improving arm and hand function in stroke patients: A review. *Journal of Neurology*, 249, 518-28.

Wolfe, C., Rudd, A., Beech, R. (Eds.) (1996). Stroke Services and Research: An overview with recommendations for future research. London: Stroke Association (Category: A1).

Wu, C., Trombly, C. A., Lin, K., Tickle-Degnen, L. (2000). A kinematic study of contextual effects on reaching performance in persons with and without stroke: influences of object availability. *Archives of Physical Medicine and Rehabilitation,* 81, 95-101.

Yelnik, A. P., et al. (2000). Perception of verticality after recent cerebral hemispheric stroke. *Stroke*, 33, 2247-53.

Youdas, J. W., Garrett, T. R., Suman, V. J. (1992). Normal range of movement of the cervical spine: An initial goniometer study. *Physical Therapy*, 72, 770-780.

Youdas, J. W., Carey, J. R., Garrett, T. R. (1991). Reliability of measurements of cervical spine range of motion- comparison of three methods. *Physical Therapy*, 71, 98-104.

Young, J. B., Forster, A. (1992). The Bradford community stroke trial: the results at six months. *British Medical Journal*, 304, 1085-89.