UNIVERSITY OF SOUTHAMPTON

FACULTY OF LAW, ARTS & SOCIAL SCIENCES

School of Education

Replicating the clock drawing test among year 1 and year 2 children: What can we learn from their errors?

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Thesis for the degree of Master of Philosophy

September 2005

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

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REPLICATING THE CLOCK DRAWING TEST AMONG YEAR 1 AND YEAR 2 CHILDREN: WHAT CAN WE LEARN FROM THEIR ERRORS?

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This thesis is concerned with investigating a distinct application of number words and symbols - that of 'telling the time', for which few empirical studies involving young children exist. Its importance as a skill is recognised in the government's National Numeracy Strategy (1998). It can be taught through various methods e.g., ICT; rote-memorisation, but without knowing which aspects children find most difficult, teachers may find it difficult to identify which areas they need to concentrate on.

For adults however, there is a plethora of studies that involve assessments of their ability to 'tell the time' and 'set the clock', mostly among neurologically damaged adults (predominantly dementia), who have been tested with variants of a 'Clock Drawing Test'. What investigators do not know however, is whether the errors committed by dementia patients are also the same errors made by young children learning to tell the time - if found to be similar, this may suggest a regression of the skills and knowledge required to complete the test, which could then be used to track dementia decline / remedial progress.

Following a pilot study to primarily test the cultural validity of the Clock Drawing Test of Freedman, Leach, Kaplan, Winocur, Shulman, and Delis (1994), the main research involved applying a modified version (conditions = free-drawn; pre-drawn; examiner) to 120 participants (Year 1 children: n = 60; Year 2 children: n = 60). The study identified two main categories of clock drawing test errors committed by some participants were also those found in previous studies to have been committed by adults with dementia - perseveration errors and neglect errors. It also found that overall, children have most difficulty with hand placement (transcoding/abstraction errors) and in spatially drawing digits in their correct clock positions.

In video-taping participants', it was also possible to conclusively determine whether they anchored their clocks when drawing them i.e., drawing in the digits at the 90-degree locations (12, 3, 6, 9), and whether this made any difference to their accuracy. In the two conditions where anchoring was possible, significant differences were found between the overall clock drawing test scores of participants who anchored their clocks and those that did not, which suggests that anchoring is an important function to undertake and is a determinant of a drawn clock's overall accuracy.

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ACKNOWLEDGEMENTS

I would like to thank the Head and staff of the school that participated in this study for their time, patience and belief in the value of the research. Without them, none of this would be possible. My supervisors Gary Davis and then Keith Jones were invaluable and I owe them a debt of gratitude for their wise words and support. The unstinting support of my partner throughout meant more to me than any words of gratitude I can express to her. I have to mention my thanks to friends who readily offered the services of their children for the pilot and to the children themselves. I also have to thank Brian Butterworth at University College London, whose inspiring talk back in 1998, which included a rather poor attempt at mimicking a parrot counting, sparked off my interest in the whole area of numerical cognition, in which the roots of this thesis are based. Finally, I have to acknowledge the contribution of the schoolchildren who participated in this study (and that of their parents/guardians). The difficulties I perceived in testing 120 children, especially those in Year 1 and Year 2, were washed away by their enthusiasm and willingness to take part.

The ability of dandelions to tell the time is somewhat exaggerated, owing to the fact that there is always one seed that refuses to be blown off; the time usually turns out to be 37 o'clock.

Miles Kington
1941-
Nature Made Ridiculously Simple (1983)

1.0 INTRODUCTION

This thesis is concerned with the abilities necessary to 'tell the time'. In particular it examines the skills and knowledge involved, how it is taught at school, the types of errors that are made by young children during learning and the types committed by adults suffering from impairments. It investigates the commonalities in these error types and determines their importance both in relation to the teaching of time and in relation to the interpretations made in other investigations.

The first section of the thesis considers what the phenomenon of 'time' actually is and what is involved in being able to 'tell the time'. In section 2, consideration is given to the body of literature which deals with 'telling the time', particularly with reference to the ability of children and that of adults (predominantly with impaired abilities). Areas within the literature are then identified where knowledge is partial, from which the specific questions this study is concerned with will be explained.

1.1 WHAT IS TIME?

Despite its superficially constructivistic nature, time is deeply rooted in our linguistic institution in the sense that it is impossible to unlearn it and eliminate from our vocabulary (Matsuno, 1999; see also Bromberg, 1938). Although intuitively it may be considered a unitary phenomenon, it is not - there are many different forms of time e.g., chronological time, atomic time, universal time, sidereal time, solar time (Royal Greenwich Observatory, 2001, personal communication). Although different at a micro level, they can be considered measurements of the same underlying phenomenon, which Crump (1990) suggests can be conceived of as a succession of intervals, each lasting long enough to comprise the event which defines it. In other words, time exists through its measurement.

It can be considered to have a universal relevance in that it is the primary organising principle for most, if not all, activities in nature and in humans. For the latter, telling the time by clocks and calendars is a skill that is basic to most cultures, since appropriate beginnings and endings of work, school, and leisure activities are largely determined by arbitrary clock and calendar times rather than by sunrise, sunset, or a person's inner rhythms and needs (Harner, 1981).

The referencing of time has a long historical tradition. The Babylonians introduced the base-60 notational system sexagesimal, and its use is preserved in the Western primary lower-level measurements of time - there are 60 seconds in one minute, and 60 minutes in one hour (Friberg, 1984). However, when the measurement of a smaller unit than one second is required (e.g., as in some sports), the sexagesimal base is replaced by the decimal system, with units of measurement tending to be reported in terms of tenths of seconds, hundredths, thousandths, ten-thousandths, and so on. Terms have even been introduced for very small units of measurement of time, such as a nanosecond i.e., one-billionth of a second. Higher level units of time are not based on the sexagesimal base - one day consists of 24 hours, one week of seven days, and one year of 365 days (366 every four years). These units tend to follow naturally occurring phenomena (i.e., one day is the time it takes for the Earth to make one complete revolution on its axis; one year is the time it takes the Earth to make one complete revolution around the Sun).

The formal measuring instruments for these lower and higher level units of time differ. Higher level instruments tend to include diaries and calendars etc., whereas for the lower level, normal instrumentation consists of clocks and watches. This higher-lower level dichotomy may have important implications on how the concept of time is initially taught and learned. When learning higher level time for example, it is not strictly necessary to learn or understand the lower level, and vice versa. However, both levels have instruments which embrace the same two concepts - one that is linguistic, and the other, arithmetical (Crump, 1990). These are now examined more closely, together with other knowledge that is required to 'tell the time' successfully.

1.2 WHAT IS INVOLVED IN 'TELLING THE TIME'?

There are four primary elements which must be understood if the skill of being able to ‘tell the time’ is to be complete: concepts; functions; referencing of time; and the am/pm dichotomy, although it is important to point out that these elements are not acquired in a linear sequence. Harner (1981) suggests that an understanding of time is a gradual process – time is first experienced on a sensorimotor level; language then follows and children learn to indicate sequence, simultaneity and duration. Finally, they are able to construct a complex system of temporal relations, which according to Hubbard (1993) is a vital requirement (though will linguistically vary between cultures).

a) The Concepts

One of the first requirements is to understand that two concepts apply – a linguistic concept and an arithmetical concept.

In lay terms, the linguistic concept of time involves a distinct application of number words and symbols. It is differentiated from other applications of number words and symbols by the use of terms that identify it as a distinct measurement concept e.g., seconds, minutes, hours. In common with other measurement concepts, the words for the measurement unit are said after saying the number words e.g., “15 seconds” (Fuson, 1988).

The arithmetical concept concerns the application of functions. As time involves number words and symbols, and because it is a measurement concept, the four basic arithmetical functions of addition, subtraction, division, and multiplication can be applied. It follows that many of the arithmetic facts (number facts) originating from these functions also applies. For example, knowing that one hour is constructed by six 10 minute periods or 12 five minute periods is semantically similar to knowing that three and two combine to make five and that five decomposes to make two parts, three and two. Resnick (1989) calls this number sense. That is not to say that when learning to tell the time, children will necessarily identify or assimilate this connection immediately. Indeed, Fuson (1988) argues that children sequentially acquire different number meanings and that these vary according to context. Fuson suggests that this means for example that learning '5' decomposes to make two parts - '3' and '2', in one context will not immediately lead to realising that this arithmetic 'fact' is universal and actually applies across all contexts[1].

The linguistic and arithmetical concepts have a close co-dependency that is identical to other applications of numbers. McCloskey (1992) documents this dependency as being one that involves transcoding, where reading numbers in their symbol format e.g., 1, 2 etc. (as from a clock or watch face for example), may internally invoke a type of automatic, effortless transcoding to their number word equivalent (e.g., one, two, three etc.). In other words, when observing digits, their number-word equivalents become invoked.

If observing digits within a time-reading situation, there is a requirement via the use of linguistic terms to identify these digits as applying to time (e.g., hours, minutes etc.). This aspect is straightforward; if a clock or watch is used then children can learn that the digits are being used in a 'time' situation. However, to actually understand and manipulate 'clock' time, a great deal of other information must be assimilated.

b) Clock Functions

The second element required for the successful development of the ability to 'tell the time' is an understanding of the functions of the clock hands i.e. that they communicate time - that the smallest hand refers to the hour, that the longest hand relates to minutes, and that the other hand (if present) refers to seconds. This of course only applies to instruments with analogue faces – the multiplicity of the types of clocks and watches produced means that although they are all measuring and displaying the same 'time', the knowledge or skills required to read that time can differ substantially. For example, with instruments such as those with wholly digital faces, there must be an understanding of the function of the hour – minute separator e.g., a colon, as in "12:45". For faces with no digits displayed but still with hands, spatial knowledge of the digit positions is required.

c) Referencing of Time

Related to the linguistic concept of time, the third element is an understanding of how

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1 Support for this also comes from Harner (1981), who found evidence of children attempting to apply arithmetic facts in a time-learning context.

digits in time contexts are referenced[2] - a hand pointing at seven may be referred to as 'seven', 'twenty-five to', or 'thirty-five past'; a hand pointing to a nine may be referred to as 'quarter-to' in addition to 'nine', 'forty-five', or 'fifteen' (Kerslake, 1975). There are also the multi-references of the same time that are possible (Harner, 1981). For example, in English the time '7:35' can be linguistically referenced in a number of ways – 'twenty-five minutes to eight', 'twenty-five minutes *before* eight', 'thirty-five minutes past seven', 'thirty-five minutes *after* seven', or simply 'seven thirty-five'[3]. Further though possibly less common terms are also possible e.g., 'twenty-five *before* eight'. These terms are semantically identical even though their reference points - given in relation to the previous hour or the next hour, are different[4].

Of all elements involved in 'telling the time', this is likely to be the most the most difficult. Indeed, according to Freedman, Leach, Kaplan, Winocur, Shulman and Delis (1994), the multi-referencing of digits poses the greatest difficulty for learning to tell the time. This may also be due in part to cultural and linguistic differences.

d) AM or PM

The final element concerns the referencing for part of the day - a.m. (i.e., ante meridian) or afternoon/evening - p.m. (i.e., post meridian). This is required for basic arithmetic fact reasons - as there are 24 hours in a day and only 12 hour digits to identify the hour of the day, each of the 12 digits must be used twice[5]. However, this knowledge is not absolutely necessary when learning to tell the time as the context will often identify whether the time in question is *am* or *pm*. It is also not necessary or even possible when setting the time on an analogue clock.

1.3 TEACHING OF TIME

By 5 years of age, children tend to have a large time vocabulary (e.g., Harner, 1981; Springer, 1952), which can form a good foundation to be built upon by formal

2 Strictly speaking, this forms part of the linguistic concept as identified in 1.2a. It is presented separately here for clarity.

3 The terms 'before' and 'after' can be particularly difficult to grasp as they can have either a spatial or temporal reference (Harner, 1981).

4 Different languages and different cultures may not have the same degree of multi-referencing of the same time as in English.

5 This does not apply to instruments with a 24 hour display.

education. Given that 'time' is a form of measurement, and given the application of arithmetic facts that apply, it is not surprising to find that from a teaching perspective, 'time' can fall broadly within a mathematical domain.

There are a number of different ways in which 'telling the time' can be taught. For example, the rote-memorisation approach adopted by teachers when teaching how to count (e.g., Ginsburg, 1977; Fuson, 1988; Wynn, 1990), is also often applied to the teaching of clock time (e.g., Kelly and Burke, 1998; Kerslake, 1975). Recent technological advances however have provided alternatives. For example, 'Tell the Time' is an ICT based interactive teaching program available from the Department for Education and Skills (see also Messer, Mohamedali and Fletcher, 1996). There are also books which may indirectly help children learn about the concepts of time (e.g., Eric Carle's 'The Grouchy Ladybug').

The importance of being able to tell the time cannot be overstated. This importance is recognised by the Department for Education & Skills, who in the National Numeracy Strategy (1998) set out a series of levels that pupils should achieve. In the Strategy's 'Framework for teaching mathematics: Reception to Year 6' and under the broad heading of 'Measures', it is clearly stated that pupils should be taught to:

> *"Understand and use the vocabulary related to time; know and use units of time and the relationships between them; read the time from clocks; solve problems involving time, and explain how the problem was solved."* (p78)

There are a series of key outcomes at different years of schooling that assess pupils against this objective. For example, Year 1 pupils should be able to read the time to the hour or half hour on an analogue clock. The application of number facts in measurement of time situations are also assessed through questions such as 'How long is it from 2 o'clock to 6 o'clock?', and 'What time was it 3 hours ago?'.

At the end of Year 2, pupils should have a greater number sense in relation to time e.g., they should know that 1 week = 7 days, 1 day = 24 hours, 1 hour = 60 minutes, 1 minute = 60 seconds. Additionally, they should be able to read the time to the half or quarter hour on an analogue or digital clock.

1.4 SUMMARY

The linguistic referencing of time, arithmetical functions, dual representation of digits, and multi-referencing, are all crucial components in the skill of being able to 'tell the time'. Of less importance is the ability to reference morning or afternoon/evening.

Given its relevance in human activities, there is an extensive requirement for this skill to be acquired across most of the globe. Fortunately, the clockface is an almost universally understood symbol and can therefore be used to assess participants of diverse social and cultural backgrounds (Kelleher, 1993; Watson, Arfken and Birge, 1993). In England, its importance as a skill to be developed at an early age is recognised through its inclusion in the National Numeracy Strategy (1998), with key ability milestones at different years of schooling outlined.

2.0 AN OVERVIEW OF PREVIOUS RESEARCH

This section presents a summary of previous research conducted into the skill of being able to 'tell the time' among those of young children and adults. It is organised as follows.

Section 2.1 looks at clock time studies undertaken among young children. Section 2.2 introduces the Clock Drawing Test (CDT), which is the primary research tool used with brain-damaged adults to assess their intact and impaired skills. Section 2.3 looks in more detail at the types of errors made by brain-damaged adults in CDTs; section 2.4 looks at how clock drawing may be conceptualised; section 2.5 examines the methodological issues arising from CDTs; and section 2.6 provides a summary of the issues arising from this section.

2.1 'TELLING THE TIME' AMONG YOUNG CHILDREN

Surprisingly, whilst extensive research has been conducted into the time-understanding abilities of [predominantly clinically-based] adults, little research has been conducted into the abilities of children (Cohen, Ricci, Kibby, and Edmonds, 2000; Dilworth, Greenberg, and Kusche, 2004). For the small number that has been undertaken, there is no apparent theoretical framework[6]. It is not clear whether researchers consider 'telling the time' as falling within a broad cognitive domain, a mathematical domain, or whether it has its own particular category.

One of the first studies that examined young children's knowledge of clock time was undertaken by Springer (1952). As part of a series of tasks given to a sample of 89 children aged 4-6 in individual interviews, participants were shown an analogue clock face and asked to tell the time when it was set 8:00, 10:00 and 12:00, and then at half and quarter hours for these times. They were then asked to set the clock at 2:00 and 9:00, and at the half and quarter hours for these times.

Springer analysed the findings by age and found that the proportion of children who were able to tell the time increased at each successive age - 77% of 4 year-olds failed

6 That is not to say that any framework is homogenous in terms of practitioner agreement on subject matter, available methods and assumptions made.

to identify any of the times, compared with 28% of 5 year-olds and 10% of 6 year-olds. A further finding applying across all ages was that hours were the least difficult to identify, the half-hours next, and the quarter hours the most difficult. That is not to say the same proportion of participants in each year who could correctly identify one hour time correctly identified each hour time. Indeed, 8 o'clock was the hour correctly identified most frequently in each year; 10 o'clock next, and 12 o'clock least frequently. (Similarly, there were differences in the proportions of participants in each year correctly identifying each of the half-hours, and in the proportions correctly identifying the quarter-hours.)

Perhaps not surprisingly, Springer found that fewer of the children were able to set the clock accurately than were able to tell the time, although accuracy increased with age. As found in the previous task, participants were more accurate in setting the hours than in setting the half- and quarter-hours.

Although there were commonalities in the errors made by the participants in telling the time and setting the clock, these differed according to age. Next to 'other' (57%), the most common error made by 4-year-olds was 'inaccurate identification of numbers' (13%), followed by 'hour identified by the long hand' (11%). In contrast, 'minutes incorrect, hour correct' had the highest error rate for 5-year olds (27%) and 6-year olds (44%).

From these findings and the qualitative findings from the interviews conducted with the participants, Springer suggested that 'telling the time' and 'setting the clock' were sufficiently different processes in the early stages of learning, and that there was a set sequence for the acquisition of overall clock time knowledge:

1) Ability to tell the time of activities which occur regularly

This initially commences with descriptive temporal terms such as *early* or *late*. Alternatively, a sequence of activities may be cited (e.g., 'Get up, eat breakfast, then school starts'). Next, an unreasonable time is given. Then a reasonable but incorrect time. Finally, the correct time is given.

2) Ability to tell the time by a clock

Knowledge of the hour times are first. These are followed by the half hours and finally, the quarter hours.

3) Ability to set the clock

Knowledge of the hour times are first. These are followed by the half hours and finally, the quarter hours (identical to the sequence of telling the time).

4) Ability to explain why the clock has two hands and how each operates.

The terms used differ according to age group (and will be related to an individual's linguistic development). At around 6 years of age, mature explanations comparable to those an adult would use are given.

This study was important, being probably the first to document the development of clock time knowledge. However, the linear sequence appears prescriptive and it is not clear what would actually constitute mastery of a particular stage i.e., whether once a stage is completed, tasks designed to test that stage should be error-free. As Wilkinson (1984) suggests, the age at which children first appear to know a concept or exhibit a skill can vary substantially according to the demands of the task with which the concept or skill is assessed, and that they may perform well on some tasks but poorly on others that are similar or even identical[7]. Indeed, in Springer's study, the finding that there were differences within each age group who could correctly identify 3 different hour times suggests that some of the correct responses could have been guesses and/or experiential rather than concrete knowledge. Springer's linear sequence of stages may therefore be too simplistic and difficult to assess accurately.

In another study, Forer and Keogh (1971) questioned whether temporal confusions are part of a generalised learning problem or whether they reflect specific cognitive or perceptual disabilities. They asked two major questions of importance – 'do children with school learning problems differ from normal achieving children in perception and understanding of time concepts?', and 'are there differences in perceptual or cognitive aspects of time understanding for learning disabled

7 Wilkinson calls this 'variable knowledge' (see also Harner, 1981).

children?'. The authors developed a Time Understanding Inventory to address these questions, which included four subtests relating to clock drawing – draw a clock, clock matching, clock fill-in, and time recognition. The sample consisted of males classed as 'learning disabled' (LD) (n = 46; mean age = 131.63 months; sd = 14.36), and a normative sample of 146 across grades 1-6 (unfortunately, no breakdown of average age or *n* in each grade was provided). Forer et al (1971) found that although the LD were similar in chronological age to 5th grade participants, their results were significantly lower on the clock drawing subtests. Their results were actually more similar to those of 2nd grade participants (p = ns). Forer et al (1971) concluded that LD had less mastery of cognitive and perceptual aspects of time understanding than normal achieving males of comparable age and IQ, and that this was a generalised rather than a specific disability. In other words, LD participants were suffering from a generalised developmental lag.

More recently, Cohen et al (2000) applied a 'Clock Drawing Test' to a large normative sample of 429 schoolchildren aged between 6-12 years (average = 8.89; sd = 1.77), with near gender parity (males = 210, females = 219). Participants were instructed to 'draw the face of a clock and make the clock say 3:00'; this was followed by a further condition with two tasks where participants were provided with pre-drawn clocks and asked to draw the hands to indicate the times of 9:30 and 10:20. In essence, Cohen and colleagues found that at age 6, most children had a basic conceptualization of a clock, by age 8, most could set the time, and by age 10, most could construct a clock face. The findings basically suggested an age-related developmental progression in terms of ability to set the time (by the hour, half-hour and by minute) and in clock construction. In broad terms, they support the findings of Forer et al (1971).

Dilworth et al (2004) undertook a longitudinal study of clock drawing ability among a non-clinical sample of 320 schoolchildren, which involved testing at two different time points, 3 years apart (average age at time one = 7.5 years; sd = 0.8; range = 6-10 years; average age at time two = 10.3 years; sd = 0.82; range = 8-13). This study utilised a pre-drawn condition and a copy condition. In the pre-drawn condition, participants were provided with a pre-drawn circle and asked to set the time at '10 after 11'; in the copy condition, participants were required to copy a clock. A battery of other neuropsychological tests was also administered. Dilworth and colleagues found that general intelligence was a significant predictor of performance on both CDT tasks but accounted for more variance in the draw condition.

The findings of Springer (1952), Forer et al (1971), Cohen et al (2000) and Dilworth et al (2004), although arising from studies with different research questions, different designs, instruments, and with different samples, holistically suggest that clock drawing and knowledge of temporal relations are developmental in nature (see also Gothberg, 1949).

2.2 THE CLOCK DRAWING TEST

Perhaps surprisingly, there is no one single Clock Drawing Test (CDT). Instead, investigators have developed a number of variations around the same theme – that of the analogue clockface[8], with each tending to claim that their particular CDT has advantages over others on given areas (e.g., predictive ability; ease of application; reliability). The primary application of CDTs has been in clinical settings as a screening device, particularly for various forms of dementia, as investigators consider it to measure a wide range of discreet factors known to decline (e.g., Sunderland et al, 1989; Wolf-Klein, Silverstone, Levy, Brod and Breuer, 1989; Agrell and Dehlin, 1998; see also Death, Douglas, and Kenny, 1993; Manos, 2005, who suggest the CDT can be used in the routine assessment of cognitive impairment of the elderly)[9].

However, it has been around in various guises since the early 1900s when it was used to assess constructional apraxia (Watson et al, 1993). Since then, developments have led to CDTs being used to evaluate symbolic representation, to assess executive or praxic functions (e.g., Freedman et al, 1994; Death et al, 1993), to test temporoparietal function (e.g., Wolf-Klein et al, 1989), and to measure visuospatial skills (Ainslie and Murden, 1993; Agrell et al, 1998; Ishiai, Sugishita, Ichikawa, Gono and Watabiki, 1993). As may be expected given these differences, CDTs can differ quite

8 But see Royall, Cordes, and Polk (1998) whose 'CLOX' test allows participants a free unprompted decision as to which clockface to draw - the digit type (Arabic, roman numerals), size of clock and hands, hand type (e.g., hands as arrows), and even clock type (e.g. alarm clock / wristwatch / wall clock etc.)

9 See also Freund, Gravenstein, Ferris, Burke and Shaheen (2005) whose CDT was used to predict older adults with declining driving competence (albeit on a simulator).

substantially across studies. Indeed, CDTs tend to incorporate one or more of four distinct designs:

1) Free-drawn - participants are asked to draw a clock and then asked to set a time on it
2) Pre-drawn - participants are provided with a clock contour and asked to put the numbers in and then set a time on it
3) Copy - participants are given a piece of paper with a mimeographed clockface complete with digits and centre drawn, and asked to copy it (normally on the same piece of paper)
4) Examiner - participants are given a piece of paper with a mimeographed clockface complete with digits (and sometimes a drawn centre), and asked to set a time on it

A cognitive neuropsychological framework tends to pervade CDT studies conducted with clinically-based adults. As theoretical frameworks can have important implications on the types of research questions addressed and the range of methods available, an understanding of the current study may be enhanced if the cognitive neuropsychological framework is outlined together with some of its assumptions.

Cognitive neuropsychology is a hybrid term applied to the analysis of those handicaps in human cognitive function which result from brain injury (McCarthy and Warrington, 1990). It proceeds from the assumption that systematic analyses of acquired cognitive deficits can offer insights into the structure, functioning, and dissolution of normal cognitive systems (McCloskey, Aliminosa and Macaruso, 1991). It draws upon neurology and cognitive psychology for insights into the cerebral organisation of cognitive skills and abilities (Martin, 1998). The primary assumptions of the framework are that brain damage can have selective deficits, disrupting some components of a cognitive system while leaving others intact, and that the cognitive systems disrupted by brain damage do not undergo a functional reorganisation in which a cognitive architecture substantially different from the normal architecture is created (McCloskey, 1992). In other words, it is assumed that the brain has a preset organisational structure that contains a number of operational systems which, following brain damage, can be selectively impaired whilst leaving their design intact. A considerable body of research has been undertaken using these assumptions, which are primarily case study based (see, e.g., Martin, 1998; Campbell and Conway, 1995). There are however, drawbacks to this approach; e.g., investigators tend to concentrate on how and why participants make errors rather than on how and why they succeed. Generally speaking, this means that models or theories of cognitive systems have been empirically informed and tested by cognitive impairment rather than by success.

2.3 Classification of errors found in Clock Drawing Test studies

Studies that have employed Clock Drawing Tests (CDTs) have tended to concentrate on their efficacy to predict the presence or degree of dementia (mostly Alzheimer's Disease) rather than how errors might reflect decline in distinct neurocognitive domains[10]. This is commonly achieved by scoring various dimensions of CDTs (depending on tasks) by a patient group and by a control group. On some scales, the higher the score the more accurate the clock (e.g., Mendez, Ala and Underwood, 1992; Freedman et al, 1994), on others the reverse is posited (e.g., Watson et al, 1993).

In some studies, the sensitivity and specificity of the CDT employed are calculated and expressed[11]. Sensitivity has been reported in the range 77% (e.g., Wolf-Klein et al, 1989; Death et al, 1993) to 87% (Watson et al, 1993). Sunderland et al (1989) suggests that if a CDT achieves a sensitivity of 80%, it will match the correct Alzheimer Disease diagnosis rate from all other antemortem methods. Specificity has been reported in the range of 77% (e.g., Kirby, Denihan, Bruce, Coakley, and Lawlor) to 87% (e.g., Death et al, 1993) though these differ between patient groups.

Although most studies employ a quantitative scoring of a CDT, in some, qualitative analyses have been undertaken which have identified important differences in the errors made by different patient groups; e.g., Rouleau, Salmon, Butters, Kennedy and

10 But see Cohen et al (2000) and Dilworth et al (2004) who applied CDTs to non-clinically based children.

11 Sensitivity is a straightforward calculation which helps indicate how sensitive a measure is at detecting differences on a given variable. It refers to the proportion of people with an impairment who are 'tested' and found to have that impairment, and is often referred to as the 'true positive rate'. Specificity refers to the proportion of people without an impairment who are 'tested' and found to be normal, and is often referred to as the 'true negative rate'.

McGuire (1992) found the types of errors made by Alzheimer Disease patients differed from those of Huntingdon's Disease patients, even though both are progressive dementias[12].

Given the different CDT designs, the scope for errors and the type of errors possible differ. For example, in a pre-drawn condition, contour errors, hand placement and digit errors are all possible; in an examiner condition, only hand placement errors are possible. Cohen et al (2000) lists a number of error types found in the adult literature across all conditions, including: omission, repetition of numbers, deficits in the spatial arrangement of numbers (including neglect and poor planning), perseveration, incorrect placement of hands to a specified time, and incorrect proportion of hour and minute hands. These errors can be loosely classified as falling into one of four different error groups:

1) Perseveration

Perseveration is the continuation or recurrence of activity without an appropriate stimulus and is a behavioural characteristic of dementia, even in the early stages (Rouleau et al, 1992; Rouleau et al, 1996). It is common in patients suffering from frontal lobe lesions (e.g., Janowsky, Shimamura, Kritchevsky and Squire, 1989; Martin, 1998). In studies employing CDTs, it tends to be evidenced through two primary means - drawing more than two clock hands or writing beyond 12, though the scope for exhibiting it will be heavily dependent on the actual task demands. Many studies involving dementia patients tend to have one or more distinct 'perseveration' error classifications (e.g., Wolf-Klein et al, 1989; Rouleau et al, 1992), but some do not (e.g., Sunderland et al, 1989). In longitudinal studies involving dementia patients, the frequency with which it is exhibited tends to increase (e.g., Rouleau et al, 1996). Perhaps not surprisingly, perseveration tends to be omitted from studies involving non-clinically based children (see e.g., Dilworth et al, 1994; Cohen et al, 2000).

2) Neglect

Neglect is often referred to as spatial neglect, spatial hemineglect or hemi-

12 See also Cahn-Weiner, Williams, Grace, Tremont, Westervelt and Stern (2003).

inattention, and refers to a failure to report, or respond, or attend to stimuli or events in the hemifield contralateral to brain injury (Martin, 1998). It can be caused by lesions in either the left or right parietal lobe (Agrell et al, 1998).

In terms of clock drawing, people suffering from left hemispatial neglect may place all 12 numbers on the right half of a clock face only (i.e., the first 2 quadrants) or place correctly only the hours 12 to 6 on the right side (Ishiai et al, 1993). Right hemispatial neglect is evidenced by placing the numbers on the left half of a clock face (i.e., quadrants 3 and 4) or by correctly placing the hours 6 through to 12 in the 3rd and 4th quadrants. Essentially, neglect is evidenced by omitting numbers halfwise (Agrell et al, 1998), though some investigators have defined neglect in CDT studies as not using a quadrant of space; e.g., Cohen et al (2000)[13].

When investigators specify a time to be drawn in, they also tend to select times which require the hour and minute hands to span both hemispaces, because if patients are free to decide, those suffering from neglect may select times requiring both clock hands to be spatially located in the contra-neglect field (Agrell et al, 1998; Freedman et al, 1994; Ishiai et al, 1993).

Interestingly, Rouleau et al (1996) report that dementia patients rarely exhibit neglect.

3) Hand Placement

In some studies, the placement of the hands is given more weighting in the scoring than any other dimension of the clock (e.g., Sunderland et al, 1989), which presumably means the authors consider clock hands are first and solely affected in dementia and that errors in the representation of numbers and the clock face occur later (Rouleau et al, 1992). As other investigators have pointed out, this means that in CDTs that are scored on a hierarchy, irrespective of whether the clock hands are correctly drawn/positioned, if there are errors in the clockface representation or number representation, a lower score will have to be given.

13 Transposing the numbers from the left side of a clock to the right or vice-versa can be construed as evidence of *allesthesia* (see Martin, 1998).

There is however, support for the importance of the clock hands. For example, Esteban-Santillan, Praditsuwan, Ueda and Geldmacher (1998) consider that the placement of hands is the most abstract feature of clock drawing. In their study, they found that they could correctly predict the presence of dementia in 94% of cases by using a particular cut-off score on clock hands alone; this is actually higher than most antemortem methods. Indeed, according to Sunderland et al (1989), if CDTs can correctly predict the presence of dementia in 80% of cases then they will match the correct AD diagnosis from all antemortem methods. Other investigators (e.g., Watson et al, 1993) do not even include clock hands in their scoring system yet still claim a high success rate in being able to distinguish dementia patients from controls.

4) Digit Errors

Given that the digits on an analogue clock constitute a major dimension of its appearance (and hence are included in virtually all CDTs as part of a task instruction), it is not surprising that errors made in their spatial placement (e.g., outside the clock contour - see Rouleau et al, 1992), their size (e.g., too big relative to the size of clock contour), their spacing (e.g., lack of or too many numbers in one or more of the four quadrants that constitute a clock face – see Watson et al, 1993, below), their sequencing, and their direction (counterclockwise), are of particular interest to investigators and are reflected to some degree in their scoring of drawings.

Watson et al (1993) found that the number of digits in the four quadrants had by far the best agreement with the diagnosis of dementia (this particular study required participants to set the numbers only on a pre-printed clock circle i.e. there was no instruction to set a time). Indeed, these authors found they could discriminate demented from non-demented participants by determining the number of digits drawn in the fourth quadrant. (Mendez et al, 1992, also included quadrants in their scoring criteria but did not determine whether this in isolation was sufficient to discriminate dementia patients from controls.)

Summary

Although there are important differences within them, in broad terms the errors made by adults in CDTs can be grouped together into four main categories -

perseveration, neglect, hand placement, and digit errors.

Intuitively, evidence of perseveration in CDTs may not be considered normative given its rather bizarre manifestation. However, given that frontal lobe dysfunction is associated with perseveration and given that neuronal cell loss associated with ageing occurs prominently in the frontal lobes (Shimamura, Janowsky and Squire, 1991), perseveration can be found in normal elderly participants. What is not clear however is whether perseveration can also be found during the normal developmental stages of skill acquisition.

Similarly, the manifestation of 'neglect' may intuitively also suggest impairment. However, whether it is an impairment or not in CDTs will be heavily dependent on task demands and also on visual characteristics. For example, if a participant is instructed to *'draw a clock and put in all the numbers'* (e.g., Rouleau et al, 1996; Ainslie et al, 1993), it is quite possible that deficits in planning and concentration could lead to all the digits being display in the first 2 quadrants, i.e., occupying the right hand slice of the clock only (Rouleau et al, 1992). In this example, it would be erroneous to conclude that the participant is suffering from 'left hemispatial neglect' from their CDT alone. Interestingly, Cohen et al (2000) in their study of normative clock drawing in children suggested that neglect was specifically related to planning ability and that it was developmental i.e., as skills develop, neglect reduces.

It is also possible that poor drawing skills, i.e., an inability to draw a circular clock contour, could lead to a mistaken classification of neglect. In CDTs where clocks are pre-drawn and the participant is asked only to only set a time that spans both hemispaces, finding that the participant locates both clock hands in one hemispace could also lead to an erroneous judgement of neglect, as other skills may be at fault. There can nevertheless, be clear evidence of neglect in CDTs[14] (though it should be noted that there is no accepted standard for the measurement of neglect, Agrell et al, 1998). For example, a clock with digits displayed only in the third and fourth quadrants would not normally be considered a planning or concentration deficit.

14 See e.g., di Pellegrino (1995).

The remaining two error types - hand placement and digit errors, are more plausible as normative errors made during the learning stages of clock time - hand placement because it is the most abstract feature of clock drawing (Esteban-Santillan et al, 1998) and because it is the penultimate stage in learning to 'set the clock' (Springer, 1952); and errors in digits because getting them right requires planning and concentration (e.g., Death et al, 1993), which when learning a new skill, especially in young children, may require practice. This leads to the question of how many and which of these error types are those that are normally made during the learning of clock-time and 'setting the clock' and which ones are peculiar to neurological impairment / ageing.

2.4 How is clock drawing conceptualised?

Investigators have tended to concentrate on the skills and knowledge required to complete Clock Drawing Tests (CDTs), how successful CDTs are at detecting the presence of, or degree, of dementia, and on the associated neurocognitive domains involved. Of less importance has been how CDT skills/knowledge may be conceptualised. However, the findings from a number of studies point towards a schematic structure for clock drawing[15].

For example, French and Harris (1993) and Richard, French and Harris (1998) found that when participants were asked to draw a clock from memory (with Roman numerals), they typically misrepresented the 4 as 'IV' rather than the correct IIII. This was not found in a copy condition. Participants in the memory conditions were also more likely to [incorrectly] draw the digits vertically rather than in their centripetal orientation. French et al (1993) and Richards et al (1998) suggested that their findings were evidence that CDTs are schema-based.

There is also anecdotal evidence from neuropsychological studies conducted in numerical cognition, where the functional independence of calculation components

15 A schema is used here to refer to a set of discrete, abstract knowledge structures that are applied to a particular event or circumstance and involve a fixed core of information. According to schematic theory, the knowledge stored in memory is organised as a set of schemas or knowledge structures, which represent the general knowledge about objects, situations, events, or actions that has been acquired from past experience (Cohen, 1989). For a more detailed discussion of schematic theory, see Groeger (1997).

(e.g., addition, subtraction, number facts) has considerable support (e.g., McCloskey, 1992; Girelli and Delazer, 1996; McNeil and Warrington, 1994; see also Butterworth, 1999). For example, Dehaene and Cohen (1997) report their case-study of MAR (an adult patient who had suffered brain damage). Whilst MAR had a series of impaired calculation-related abilities, he still had intact clock time knowledge. For instance, he could perform computations with hours that he was completely unable to perform in the abstract - he could tell how much time elapsed between hours and could convert hours from the 24-hour format to the 12-hour format. When presented with very similar addition or subtraction problems with a second operand close to 12 (e.g., 5 + 12, 3 + 11 or 22 - 12), he failed completely. Hence, he was able to compensate for his arithmetical impairment when the numbers had a concrete referent in the clock time domain, but not otherwise[16]. This was similar to a further case reported by Dehaene et al (1997) - DUV who, when asked to bisect 6 and 10, failed repeated attempts before stating:

> "I'll think of a clock face, it will help me…" (p249)

(Even then, DUV failed, stating '8½'.)

Although this does not directly provide evidence of a distinct CDT schema, it does nevertheless suggest that knowledge of clock-time is held and accessed differently from that of general numerical information (though for DUV, it could simply have been a case of a retrieval strategy based on spatial visualisation). This raises an important point - that of the strategies used to complete clock drawing tasks. A schematic explanation does not necessarily mean that CDT skills and knowledge are held in set structures with a single mode of access. As Siegler and Engle (1994) found in the case of KBK (a brain damaged adult), and point out from numerous studies with children, there are a plurality of strategies that participants call on when attempting to complete tasks (at least those falling within a mathematic domain). This may mean there are different modes of access for a schema and/or the possibility of utilising compensatory strategies if and when a schema is not accessible.

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16 Unfortunately, MAR was not given a CDT to complete or any other test requiring him to draw a clock.

2.5 METHODOLOGICAL ISSUES WITH CLOCK DRAWING TESTS

According to Freedman et al (1994), many investigators who employ a CDT instruct the participant to '*Draw the face of a clock, put in all the numbers, and set the time at....*'. Other investigators do not specify a time or do not specify a time to be drawn in until after the clock face and numbers have been drawn (even these do not specify a uniform time). In some studies, a model of a clock is provided (which is drawn and located on the test paper) and participants are instructed to copy it. In other studies, participants are asked only to set the hands at a fixed time on pre-drawn clocks, complete with contour and numbers (Agrell et al, 1998). Drawings are then analysed or scored on some criteria or rating scale and conclusions drawn. This has created a number of methodological issues with CDTs which will now be examined.

a) Skills

The differences in task demands based on CDT design (e.g., free-drawn, pre-drawn, copy, examiner) necessarily means there are important differences in the skills and/or knowledge being measured (which in turn means that different neurocognitive domains may also be involved), which as Royall, Cordes and Polk (1998) point out, means that individual performances can vary greatly as a function of the task itself. Where CDTs involve the task instruction 'draw a clock' (as in a 'free-drawn' design), many more skills are required to those required in a verbal test involving questions on 'telling the time' or in setting a time on a mimeographed clockface (e.g., 'examiner' design). In particular, in order to 'draw a clock', a participant must have an accessible memory of the representation of a clockface and be able to retrieve it (e.g., Ferrucci, Cecchi, Guralnik, Giampaoli, Noce, Salani, Bandinelli and Baroni, 1996; Esteban-Santillan et al, 1998), and they must have adequate visuoperceptual and visuomotor/visuoconstructive processes in order to translate that mental representation into a motor program for drawing it, viewing it and if necessary, correcting it (e.g., Freedman et al, 1994; Mendez et al, 1992; Wolf-Klein et al, 1989; Rouleau et al, 1992). Verbal comprehension and memory of instructions (Dilworth et al, 2004), and concentration and planning skills are also required (e.g., Death et al, 1993; Royall et al, 1998). In terms of neurocognitive domains involved, a copy condition can involve the occipital and parietal lobes whereas for a pre-drawn and free-drawn, the frontal and temporal lobes are utilised (e.g., Freedman et al, 1994)[17].

In addition, most investigators have tended to concentrate on CDT outcomes rather than on how participants tackled the task requirements, and it is possible that this has an influence on accuracy (and hence overall scoring). For example, in pre-drawn and free-drawn conditions (and possibly in copy conditions), where participants are required to 'draw the numbers in', the spatial accuracy of digits may be enhanced if participants draw the anchor numbers first i.e., 12, 3, 6, and 9, rather than attempting to draw all numbers in sequence (where any initial errors in spatial placement can have a knock-on effect in the spatial placement of all remaining digits). In some studies, anchoring has been observed to reduce the scope for spatial errors. For example, Cohen et al (2000) found that when the anchoring stimuli were pre-drawn for participants, sequencing and positioning performance significantly increased. In a study by Ishiai et al (1993), 13 of their 16 participants who drew a clock fairly well used anchoring, and 70% of a control group.

Overall, these differences in CDT task demands and hence the skills and knowledge required to complete them, means that cross study comparisons can be seriously impeded. Even the same condition between studies can be employed differently, and these differences can impact on the findings. For example, in free-drawn and pre-drawn conditions, if the instruction to set a time is given at the same time as the instruction to draw a clock (e.g., Ainslie et al, 1993; Rouleau et al, 1996), then participants may proceed differently than if the instruction to set a time is provided after the clock is drawn (e.g., Mendez et al, 1992) – if say, a required time of '10 after 11' is provided at the same time as the instruction to draw a clock, a participant may draw in the 11, 12, 1 and 2 in that order (Freedman et al, 1994) rather than commencing with the anchors (12, 3, 6, 9).

b) Clock Times and Cultural Validity

Investigators tend to select times that require the participant to recode when setting them. For example, a time of '5 after 7' requires a recoding of the '5' so that the minute

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17 Dilworth et al (2004) also point out that copy conditions are less taxing on memory and frontal lobe abilities than other conditions involving participants drawing a clock from memory.

hand is positioned on the '1' hour position. According to Freedman et al (1994) the three most widely used time settings in CDTs are: '10 after 11'; '20 after 8', and '3 o'clock'. Whereas the first two of these times require recoding and may be used to measure hemispatial neglect, the latter is presumably to tap knowledge of the 'o'clock' function i.e. the positioning of the minute hand to the 12 hour position, rather than neglect.

These three primary times raise an important issue – that of cultural validity. The wording of clock times in task instructions must be culturally biased. For example, in the United Kingdom task success for some participants could be higher if the time '5 after 7' is rephrased as 'five minutes past 7', even though they are semantically identical. There may even be particular geographical areas where some wordings may be completely understood but if posed using different phraseology would lead to higher task success. The potential for bias in findings and interpretations therefore increases. This could place severe restrictions on true international replications where task wordings remain identical.

Indeed, the impact of cultural and linguistic differences on CDT task success could be substantial, especially where there are marked differences between numeral systems. For example, Miura, Kim, Chang and Okamato (1988) point out that in English, the order of spoken and written numerals may not always agree (e.g., 'fourteen' for '14'), whereas in some Asian languages (e.g., Chinese, Japanese, Korean), the spoken numeral corresponds exactly to the implied quantity representation in the written form (e.g., '14' is spoken as 'ten-four' – 'shi-si' in Chinese; 'juu-shi' in Japanese; 'shib-sah' in Korean). This means a higher degree of learning is required to speak and write in the English numeral system than in these Asian languages, with the former needing a higher span of numerals learnt by rote and a need to learn the decade terms (Miura and Okamoto, 2003).

This could have important implications on the range of potential errors in CDTs across different countries. For example, an English CDT verbal task instruction along the lines of '*set the time at fourteen minutes past four*' necessarily requires a cognitive recoding of 'fourteen' to '14'. In the same task instruction in Chinese, Japanese or

Korean, this translation is not required given that it would be provided as 'ten-four'.

There is also the possibility that CDT task success may be influenced by an interaction of linguistic differences within the mathematical domain with participants' strategy choices. Miura et al (2003) suggest that the whole-part concept of common fractions may be easier to understand in Asian languages than in English, as the concept of fractional parts is embedded in the mathematics terms used for fractions in the former (e.g., one-third in Japanese is spoken as '*san bun no ichi*', the literal translation of which is '*of three parts, one*'). In contrast, the English term '*third*' provides no such cue. In terms of the potential impact on CDT task success, this may mean the instruction, e.g., '*set the time at quarter past five*' could offer an additional strategy choice to Asian participants (or at the very least, an additional cue) than English-speaking participants, given that in an Asian language, the '*quarter*' may be translated into '*of four parts, one*'. It is not clear then what the influence of linguistic terms used in task instruction on success may be. This raises the possibility that different languages and different linguistic terms may offer additional cues or additional strategy choices to English-speaking participants.

c) Scoring / Analyses of CDTs

Another factor that makes the CDT difficult to interpret is the existence of several scoring systems with varying degrees of complexity (Esteban-Santillan et al, 1998; Ishiai et al, 1993). Table 1 provides a brief snapshot of some of the many scoring mechanisms and design-types that have been employed in CDT studies.

Table 1: Rating/Scoring used in a sample of studies employing a Clock Drawing Test

Authors	CDT Design	Rating / Scoring Used
Death et al (1993)	Pre-drawn	Pattern match based on 4 different classes
Freedman et al (1994)	Free-drawn Pre-drawn Examiner	Score out of 15 Score out of 13 Score out of 11
Ishiai et al (1993)	Pre-drawn	Score out of 4
Mendez et al (1992)	Free-drawn	Score out of 20
Rouleau et al (1992) Rouleau et al (1996)	Free-drawn (& a copy condition)	Score out of 10 (author amended version of the Sunderland et al, 1989 scale)
Sunderland et al (1989)	Free-drawn	Score out of 10
Watson et al (1993)	Pre-drawn	Score out of 7 (where 0 = accurate)
Wolf-Klein et al (1989)	Pre-drawn	Pattern match based on 10 different classes

As with all scoring/rating/classification systems, each has their own particular strengths and weaknesses. For example, the rating used by Wolf-Klein et al (1989) has been found in studies to be very successful at identifying older persons at risk of cognitive decline (see Ferrucci et al, 1996; Rouleau et al, 1996); it has also been found to be less affected by the level of education of participants than other scoring systems (Ainslie et al, 1993).

The scoring system and study of Freedman et al (1994) is of particular interest, as it is probably among the most comprehensive CDT studies, given that it employed 3 different CDT designs and because of the large sample size - Freedman and colleagues tested 348 neurologically normal individuals ranging in age from 20 to 90 years. They subdivided the participant pool into seven age groups by decade: 20-29, 30-39, ..., 80+ years, with an achieved *n* of 40 minimum to 76 maximum per decade. In order to capture the main elements of the diverse CDTs they found in the literature, Freedman and colleagues devised a CDT consisting of three conditions.

The first condition - free drawn, required participants to draw all aspects of a clock, including the contour, numbers and hands and to set the hands at a pre-specified time. This was followed by the pre-drawn condition, which required participants to reproduce the numbers and hands on a pre-drawn contour and to then set the time at a specified time. The final condition - examiner, required participants to set the hands at three pre-specified times on mimeographed clockfaces (analogue digits) with the centres clearly marked.

To determine a comprehensive scoring system, the data were analysed to determine which responses were present at a high or low rate, respectively. A subset of descriptors was selected if they occurred, or did not occur, in at least 90% of participants in the youngest age group. This list of descriptors was evaluated by Freedman and colleagues to determine which were considered characteristic of a 'good' or 'bad' clock (determined by consensus). The following was asked for each item: *'Would the presence or absence of this item in anyway contribute significantly to a good or bad clock?'* The smaller subset of descriptors was then used to establish a set of 'critical items' from which an objective scoring procedure could be developed (see Appendix A for the final list of items selected). As would be expected, the number of critical items differed by condition (free-drawn = 15; pre-drawn = 13; examiner = 11 per each of the three times).

The clock drawings were subjected to a straightforward scoring dichotomy (i.e., one-point for the presence of each critical item; no points for its omission). Subsequent analyses revealed that the mean total scores for both the 70-79 and 80+ age groups were significantly different from all other age groups (but not from each other); these age groups also had the greatest range of scores. The most common errors for these age groups included incorrect representation of the proportion of the hands and incorrect placement of the minute hand. This suggests an age-related deterioration in the memories required (or access to memories) to successfully complete CDTs.

This was arguably a seminal study due to its multi-design, its large normative sample, and its scoring. However, the question that arises is why they decided to only look at adults aged 20+. There was no empirical justification provided and no practical reason why the sample could not have included younger participants. This was a surprising omission.

Summary

CDT designs fall more or less into 4 categories - free-drawn (i.e. participant is asked to draw a clock contour, draw in the numbers and then set a time on it); pre-drawn (i.e. participant is provided with a clock contour and asked to draw in the numbers and set a time on it); examiner (i.e. participant is provided with a mimeographed clockface complete with numbers and marked centre, and asked to set a time on it); copy (i.e. participant is given a piece of paper with a mimeographed clockface complete with digits and centre drawn, and asked to copy it - normally on the same piece of paper. (Note: of the 4 categories, this particular design tends to be the least frequently employed). These differences together with a diverse range of scoring/rating systems means cross-study comparisons are compounded as the skills used and how they are measured can vary considerably. The cultural bias of task instructions, or more specifically the phraseology used in the clock times that participants are asked to draw may also negate comparisons.

2.6 SUMMARY OF PREVIOUS RESEARCH

In the adult literature, the Clock Drawing Test (CDT) is the primary tool by which skills are assessed. However, unlike many batteries, the CDT is not a uniform test that is administered to standard instructions and scored using one set of criteria, although CDT materials (piece of paper, pencil/pen) tend to remain fairly constant. The administration of the CDT can also be quick, and has been found to be less intimidating for participants to complete that a more extensive battery (e.g., Death et al, 1993; Freedman et al, 1994; Royall et al, 1998). However, there are a number of issues with their design and application.

Firstly, their construct validity - what they actually measure. There are some researchers (e.g., Kerslake, 1975; see also Gothberg, 1949), who argue that telling the time can be no more than a dial-reading exercise i.e., no knowledge of time principles or the concept of time is required in order to read/communicate a time from its instrumentation. This is unarguable – it is not necessary to know how many seconds there are in a minute, or how many minutes in an hour etc., in order to read the time from a clock or set it. However, with CDTs tending to require participants to draw clocks and/or set times, the cognitive and motor requirements extend beyond those required for a simple reading exercise. This is also supported by the finding that the convergent validity tends to be high (see, e.g., Death et al, 1993; Freedman et al, 1994;

Wolf-Klein et al, 1989).

Secondly, although not all CDTs require participants to set a time, the issue of cultural validity arises from those that do, especially in relation to task instructions. For example, a typical task instruction in studies conducted in the United States might be of the form '.....*set the hands for 10 after 11*'. If this instruction were repeated in England, task success might be less than if the instruction was re-worded to '.....*set the hands at 10 minutes past 11*'. It is also not possible to discount dialect-specific variations in how clock-times are verbally communicated.

Thirdly, the existence of multiple CDTs and the different scoring systems can make the interpretation of results difficult (Esteban-Santilan et al, 1998), and negates cross-study comparisons. The scoring systems are of particular concern, with some investigators (e.g., Mendez et al, 1992; Royall et al, 1998) questioning whether CDTs can be scored in a simple, reliable and valid manner. Although the test-retest reliability of CDTs are rarely reported, the inter-rater reliability of CDT scoring has attracted some attention, with Agrell et al (1999) documenting the inter-rater reliability of CDTs from a number of studies (with adult populations); these ranged from 0.86 – 0.97. More recently, Koch, Hahn, and Szecsey (2004) reported inter-rater reliabilities of 0.89 and 0.78 (Spearman's rank). In their CDT studies involving children, Royall et al (1998) reported an inter-rater reliability of 0.94 for their CLOX1 CDT design and 0.93 for CLOX2; Cohen et al (2000) reported inter-rater reliabilities of 0.94 to 0.98. This would seem to suggest that on scoring, many CDTs appear robust.

Fourthly, and related to construct validity is that of what is being scored and how. Although it could be argued that in instructional terms, CDTs capture or measure clock drawing ability, or rather the skills required to undertake them (e.g., graphic, planning, conceptual, perceptual, spatial), it is how the raw data is scored that heavily influences its validity and the interpretation of findings. If there is preferential scoring that affords higher scores to one particular dimension of a CDT over another, and this is not empirically justified then arguably, the scope for bias in interpreting the findings increases. Nevertheless, investigators have claimed big successes in terms of using CDTs to screen for dementia, with many reporting predictive values in excess of other antemortem methods.

Despite the multitude of scoring systems, errors made in CDTs can be loosely classed as either being errors of 'perseveration', 'neglect', 'hand placement', or 'digit', with the first two of these being mostly associated with cognitive impairment and the latter two being classed as normative. However, the conclusions investigators have drawn about the errors caused by cognitive impairment and those which are normative are not as robust as they could be - there is an important omission, which relates to children.

A conclusion drawn about the severity of a neurological condition found in adults, based on error patterns found in tasks related to 'telling the time' may be incomplete in the absence of establishing whether the same error patterns are also found in normal children during the development of the skills required - if found, this may suggest a regression of particular cognitive/motor abilities and/or distinct neurocognitive domains, depending upon the tasks involved[18].

This could have important applications. Firstly, in progressive conditions (e.g., dementia), it may be possible to track cognitive decline by mapping errors against those made during normal skill development[19]. Secondly, in other conditions (e.g., strokes), establishing where a patient's current skill is against the normal acquisition stages of that skill via an analysis of their error patterns could be used to inform their remedial programme.

The alternative finding, that error patterns are peculiar to brain-damaged patients, is

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18 Support for this argument also comes from e.g. Gainotti (1972), who conducted a study investigating the 'closing-in' symptom, which in broad terms is the tendency to draw over a model displayed on paper when attempting to copy it (though it can also be present in a number of other tasks/situations). That is, if a participant is given a sheet of paper with a drawing of e.g., a house, and instructed to copy it on the same sheet, 'closing-in' would be evidenced through the copy being made on the actual drawing itself. Gainotti found evidence of 'closing-in' in normal children and in adult patients suffering from dementia and suggested that 'closing-in' activity was an evolutionary pattern in children, whilst in dementia patients, it represented demential disintegration, or in other words, the reappearance of primitive patterns of behaviour. Evidence of 'closing-in' was also found by Rouleau, Salmon & Butters (1996) in.

19 Kelleher (1993) and Sunderland, Hill, Mellow, Lawlor, Gundersheimer, Newhouse, and Grafman (1989) also suggest that repeated use of the CDTs with dementia patients can allow the evaluation and stage of the condition to be tracked.

also important as it could further knowledge about the underlying cognitive processes and neurocognitive domains involved in particular tasks. Additionally, it could provide evidence to support the severity of localised brain-damage.

A further potential benefit derived from this and other studies conducted among young children learning to tell the time is that the findings could be potentially used to complement existing teaching techniques for time (e.g., Kelly et al, 1998; Andrade, 1992), which can be a difficult concept to teach (Kerslake, 1975; Harner, 1981) and learn (e.g., Bromberg, 1938). For example, it may be possible through the analyses of error types, to identify which particular concepts (e.g., clock function; referencing of time) children find particularly difficult. This in turn could be used to help design innovative learning approaches.

Taking these issues into consideration, the aims of the current study were to:

1) establish normative Clock Drawing Test data for young children
2) identify the differences between this data for young children and the normative data for adults
3) determine whether the errors made by adults in clinical settings are also those made by young children
4) ascertain which aspects of the Clock Drawing Test young children find most difficult (the findings of which could inform teachers as to which areas to concentrate on)

3.0 METHODOLOGY

Having outlined the purpose of the study and its theoretical foundations, the present chapter details the methodological aspects. The first section outlines the reasoning for, and details of the pilot study. It details the participants and procedures and concludes with the results and what features influenced the main study. The next section details the main study.

3.1 PILOT

Although the procedural elements of the Clock Drawing Test (CDT) devised by Freedman et al (1994) are well documented, its cultural validity has not been established. That is, whether the CDT is biased towards the participants of the culture where it was developed and applied. The aim of the pilot was therefore to determine whether the CDT, which had previously only been administered to American adults aged 20-90, could be replicated among the intended sample of young English children in the main research, or whether changes were necessary. There were two areas of particular concern. Firstly, it was important to establish whether young children would understand the task instructions. Secondly, a possibility existed that the test was biased towards an American audience.

Given these issues and the aim of the pilot, an exact replication of the procedures of Freedman and colleagues would not be sufficient, as it would merely result in a set of quantitative data. Given that the procedures do not allow any form of deviation or further interaction with participants, what was needed was a methodological design incorporating a replication of the procedures of Freedman and colleagues but one that also enabled flexible verbal interaction between investigator and participant. This would then allow the investigator to check that task instructions were understood and to vary task instructions (but for them to remain identical semantically). It was considered that combining this qualitative approach within a broad quantitative framework would enable the objectives of the pilot to be achieved.

a) Participants

An opportunist sample of six children (4 male, 2 female) was obtained through five associates of the author. Four of the participants were in Year one of their primary school education and were aged between 5-6 (three male, one female) and two were in Year two and were aged 6-7 (one male, one female). All spoke English as their first language. No payment or incentive was made for participating.

b) Procedure

In order to minimise any extraneous influence on participants' results, details of the tasks to be administered were given to parents/guardians around 5 minutes before testing was due to take place. At this time, consent for the participant was also obtained (no parents/guardians withdrew consent). Testing took place at each participant's normal residence with one or both parents/guardians present at all times during testing. Testing was undertaken informally with participants verbally encouraged to communicate any misunderstanding of task requirements (a key requirement to enable the objectives of the pilot to be achieved).

The three tasks of the CDT were replicated from those used by Freedman et al (1994), and administered in the same order. Each participant was tested individually.

1) Free-drawn condition

Participants were presented with a pencil and blank piece of A4 paper in landscape format (11inch x 8½ inch; 29.7cm x 21cm) and instructed "*I would like you to draw a clock and put in the numbers*." After completing this task, they were instructed "*Now I would like you to set the time at a quarter to seven.*"

2) Pre-drawn

Participants were given a piece of A4 paper in landscape format (11inch x 8½ inch; 29.7cm x 21cm) with a pre-drawn circle 11.7cm in diameter (approximately centered) and instructed to "*Put the numbers on the clock and set the time at 5 after 6.*"

3) Examiner

Participants were given a piece of A4 paper in landscape format (11inch x 8½ inch; 29.7cm x 21cm) with a mimeographed clock face (approximately centered) complete with digits (in analogue format) and tick marks (i.e., second/minute marks). They were instructed: "*I would like you to set the time at 10 after 8*". This task was repeated twice with identical materials but with the following instructions: *"I would like you to set the time at 10 after 11"*, and *"I would like you to set the time at 3 o'clock"*.

c) Results and Discussion

Without exception, participants did not understand the time instruction given in the pre-drawn condition "....*set the time at 5 after 6*", or in two of the examiner conditions- "....*10 after 8*" and "....*10 after 11*". However, when these were immediately modified by the investigator to more English-specific phraseology (i.e., "... *set the time at five minutes past six*", "...*ten minutes past eight*", "...*ten minutes past eleven*", participants indicated that they did understand (even though this did not result in each participant setting the correct time).

This was an important finding and suggests that the Freedman et al (1994) CDT may be biased towards an American adult population. It was therefore considered that in the main research, the CDT be modified using the revised phraseology where necessary. As the clock drawings themselves were not considered an important element of the pilot, they were not scored or analysed further.

Incorporating a qualitative approach within a quantitative framework enabled the objectives of the pilot to be achieved. That is not to say that alternative methods were not available. It may have been possible to design the pilot using only quantitative techniques (e.g., by presenting task instructions in different phraseology [for the same times] and then ascertaining whether there were significant differences depending on phraseology). However, given that the aim of the pilot was to probe and fine tune the main design, quantitative methods were rejected in favour of the interactive technique used because that enabled real-time changes and real-time interaction with each participant. In other words, the pilot was not considered a statistical exercise.

3.2 MAIN RESEARCH

The main research involved a replication (with some amendment of task instructions arising from the pilot study) of the Clock Drawing Test (CDT) developed by Freedman et al (1994) among a sample of Year 1 and Year 2 primary school children.

a) Ethics

Research with children, especially young children, requires that ethics constitute an integral part of the research design process, as issues such as informed consent, deception, stress and discomfort, and right to withdraw can become problematic. At the outset of the main study, a great deal of consideration was given to ethics - identifying potential issues (for the school, the parents, the participants, and the investigator), and how they might be addressed whilst still achieving the study's objectives. This was done in very close consultation with the School Head over a number of meetings. The following were agreed.

1) Testing would take place in a room observable at all times by other teachers/classroom assistants. The door to the room would be left open at all times;

2) Given the obvious concerns that parents/guardians may have of their child being videotaped, especially by a male researcher, it was agreed that at the end of each day, all videotapes would be provided to the School Head for inspection. This was communicated to all parents/guardians through a letter which was mailed to each potential participant's home address (see 3 below);

3) To address the issues of consent and right to withdraw, a letter to all parents/guardians was issued which detailed the main aspects of the research, and via a cut-off slip which was to be handed in to a teacher, allowed them to withdraw their child. A covering letter was sent out by the School, which supported the study (no parents/guardians withdrew consent); and

4) All participants were to be told some basic information about the tests by their teacher and encouraged to participate. The investigator would also verbally provide some information about the tests and answer participants' questions during testing (but not those which aided completion).

It was considered that these safeguards worked efficiently and effectively and contributed to the validity of the findings. There was no apparent concern from the participants on being video-taped and no visible anxiety on being tested individually by a male investigator. The observation that some participants felt able to refuse to complete a particular task or part of a task was considered a positive reflection of the ethical safeguards introduced.

b) Materials

Findings from the pilot study resulted in the Clock Drawing Test (Freedman et al, 1994) being modified. The following task instructions were re-worded:

Pre-drawn condition: "*....set the time at 5 after 6*" -> "*....set the time at five minutes past six*"

Examiner condition: "*....set the time at 10 after 8*" -> "*....set the time at ten minutes past eight*";

Examiner condition: "*.... set the time at 10 after 11*" -> "*.... set the time at ten minutes past eleven*".

All other instructions and materials were consistent: the free-drawn condition involved 1 sheet of A4 and pencil; the pre-drawn condition involved 1 sheet A4 with a circle 11.7 cm in diameter (approximately centred in landscape format); the examiner conditions involved a sheet A4 with a mimeographed analogue clock face (approximately centred in landscape format) complete with digits and tick marks (i.e., second/minute marks).

To ensure that each participant's results did not become mixed up with another participant's, each test paper in the CDT had, at the foot, entries for the child's name, sex, and year (i.e. year 1 or year 2). These were completed by the investigator at the commencement of each individual's test. Appendix B contains a copy of the complete templates used (note: there were three tests in the examiner condition but as these all used the same template, only one examiner condition template is provided.)

(A further test involving matching, counting by ones, verbal sequence, numeral recognition, counting collections. and addition. developed by Pearn, Merrifeld, Mihalic and Hunting, 1994, was also administered to participants in the same session. Results of this test will be reported elsewhere. However, it is important to note that in order to minimise the potential confounding effects of test order on results, the study employed a 2 x 2 counterbalanced design, based on school year - Year 1 or Year 2, and test order - whether the CDT was administered first or the test developed by Pearn and colleagues. Four groups were therefore formed, with parity of N in each group; n=30).

c) Participants

A Roman Catholic school in the South of England with a good socio-economic mix (as reported by the School Head), was approached and agreed to participate in the study. Participants were drawn from Year 1 (ages 5-6) and Year 2 (ages 6-7). There were two classes in each of the two years (mainly equalised in terms of numbers), resulting in an effective sample of over 120 eligible participants. Overall, a sample of 120 was achieved (60 in each year; 66 female, 54 male).

d) Procedure

Data collection commenced on 4th June 2001 at lasted ten days. Testing was administered by a male investigator aged 36 in a school room approximately 8ft x 6ft, and took place during the school day, avoiding break and lunch times. The testing room was visible at all times by other teachers and classroom assistants. Participants were tested individually and sat at a table facing the investigator. In order to determine whether participants, when completing the first two CDT tasks anchored the clocks by drawing the 90-degree digits (i.e., 12, 3, 6, 9), video-recordings were made. The video-cameras were positioned such that only the participant's hands and arms were filmed. This positioning was as follows. The video camera was positioned approximately 24 inches to the left of the participant at an approximate angle of 90 degrees; it stood on a tripod approximately 5 feet off ground level and had a focal area covering the drawing area (this was established by placing a piece of A4 paper immediately in front of the participant). Videotaping began after the participant had sat down and was told some basic information about the tests. (Videotaping was also undertaken in order to identify whether participants rotated the paper when drawing in the numbers in the free-drawn and pre-drawn conditions, and was necessary for the scoring of drawings.)

Anything which was considered to be a potential aid to the participant was removed - a clock was removed from the wall, and participants were asked if they were wearing a watch (none were). Task instructions were repeated as necessary but additional prompting was not provided. As the study involved all pupils present in Year 1 and Year 2, it was not considered necessary to establish a sampling scheme. When each participant had completed the tasks and returned to their teaching room, a new participant was selected by the teacher (but this had no particular order).

The order of clock drawing tasks was identical for each participant: free-drawn; pre-drawn; examiner (3 separate tasks):

Free-drawn:
Participants were provided with the free-drawn materials (A4 paper and pencil) and instructed "*I would like you to draw a clock and put in the numbers*". If participants failed to draw a contour, failed to put in any numbers, or indicated in some way that they did not know how to undertake the task, the task was terminated and the next condition was attempted. All other participants were instructed "*Now I would like you to set the time at a quarter to seven.*"

Pre-drawn:
Participants were provided with the pre-drawn materials (A4 paper complete with 11.7cm diameter clock contour) and instructed "*Put the numbers on the clock and set the time at five minutes past six.*"

Examiner:
Participants were provided with the examiner materials (A4 paper complete with an 11.7cm in diameter mimeographed clockface with digits) and instructed: "*I would like you to set the time at ten minutes past eight*". When this task was complete or the participant indicated they did not know how to complete it, they were provided with the next task "*I would like you to set the time at ten minutes past eleven*". That procedure was also adopted for the last of the examiner tasks: "*I would like you to set the time at 3 o'clock*".

4.0 RESULTS

This section is organised as follows. Section 4.1 documents how the data were scored and then provides descriptive statistics and the outcomes from statistical tests for each of the conditions from the Clock Drawing Test (CDT) employed. Section 4.2 documents how participants' drawings were analysed for evidence of anchoring and whether it made a significant difference to their accuracy (and hence scoring). Section 4.3 provides the main quantitative findings for each of the three conditions, and replicates the format of Freedman et al (1994). Section 4.4 provides an analysis of the errors under the four classes of perseveration, neglect, hand placement, and digit errors. Section 4.5 concludes with a summary of the results section.

4.1 DESCRIPTIVE STATISTICS

The current study replicated the three conditions of Freedman et al (1994) but with culturally revised task instructions:

1) Free-drawn (participants asked to draw a clock and then asked to set a time)
2) Pre-drawn (participants provided with a clock contour and asked to put the numbers in and then set a time)
3) Examiner (participants provided with a mimeographed clockface complete with digits, and asked to set a time). There were three separate tests for this condition, each requiring the participants to set a different time

The scoring also replicated that of Freedman et al (1994) - see Appendix A. This meant that for each of the conditions, clock drawings were dichotomously scored (i.e., one-point for the presence of an item; no points for its omission). The maximum possible scores differed across the three conditions, reflecting the different number of items: free-drawn = 15; pre-drawn = 13; examiner = 11 per each of the three tests.

Given that there were 3 conditions (though the examiner condition involved 3 separate tests), and 120 participants completing each condition (n = 60 Year 1; n = 60 Year 2), 600 drawings had to be scored; this was undertaken by the current study's author. Although no training was undertaken, the documented approach taken by Freedman and colleagues was carefully followed. However, there were issues that had to be addressed. Firstly, in the free-drawn, 2 out of the 15 scoring items appeared to be subjective - 'Acceptable contour drawn' and 'Contour not too small nor overdrawn nor reproduced repeatedly'. The definition adopted by Freedman and colleagues of an acceptable contour was any closed contour, with closure considered accurate if the line(s) used to define the contour were touching or overlapping. This definition was therefore adopted in the current study. The definition that Freedman and colleagues used for an acceptable size contour was any size that enabled a participant to draw the numbers in i.e., irrespective of shape, if it was too small to include every number then it was considered unacceptable. This definition was therefore adopted in the current study.

A scoring item applying to the free-drawn and pre-drawn conditions only - 'paper not rotated while drawing numbers' was addressed through using the videotapes. If a participant was observed to move their drawing more than once, they were judged to have rotated it.

The remaining scoring criteria for the free-drawn and pre-drawn conditions were considered straightforward. However, some of the scoring items from the examiner condition required precise measurements:

1) 'Hour hand/mark is displaced from hour target number within limits set by normative data (-3 to 3 degrees)';
2) 'Minute hand/mark is displaced from hour target number within limits set by normative data (-3 to 3 degrees)';
3) Hands are joined or within 12mm (½ inch) of joining;
4) Centre is displaced from the vertical axis within 5.0mm (3/16 inch) to the right or left of the axis; and
5) Centre is displaced from the horizontal axis within 5.0mm (3/16 inch) below the axis or 7.00mm (5/16 inch) above the axis.

Freedman and colleagues did not make it clear how they took these measurements, so it was not possible to replicate their instrumentation and procedure. Given the precision required however, it was considered necessary in the current study to design and adopt some reliable methods. For (1), contours matching the same size as the examiner clocks (11.7cm in diameter) were produced on transparencies; each contour had two hands that ran from the centre of the contour to +3° of the examiner target hour and -3° of the target hour (i.e., equidistant between the two tick marks either side of the target hour). To score, the transparency was placed over each drawing; if the end of the participant's target hour hand fell between the two hands at any point from the centre then it was counted. A similar transparency was produced to score (2). In order to quickly score (3), a thick piece of cardboard with 12mm marked off was used; this was placed at the end of one hand – if the other hand fell within the marked off area, it was counted (this was considered quicker to apply than a ruler). To score (4) and (5), a contour complete with guide cross (which spanned the contour) was printed in red ink on a transparency. The vertical line of the guide cross had 10mm thickness; the horizontal line had 12mm thickness. It was designed so that at the centre of the contour, 5mm of the vertical axis was showing to the left and 5mm to the right; for the horizontal axis, 5mm showed below the centre and 7mm above. To score, the transparency was placed over the clock – if the centre was contained within any part of the guide cross then it was counted.

Once all 600 drawings were scored, a random selection of 10% from each condition (36 in total from the 3 examiner conditions) were re-examined by the study's author; measurements were retaken and scores checked for accuracy. No changes in scores were made as a result.

Once the quality assurance was completed, the participants' school was re-contacted, supplied with the names of the participants and asked to record the special needs status of each participant against their name, i.e., level 0 (no special needs), level 1 (special needs being met by their teachers), level 2 or level 3 (special needs partly met by the Local Education Authority). This was a deliberate design in the scoring stage of the study to minimise any bias. These were then matched up with participants' drawings and analyses undertaken.

The following table provides the descriptive statistics for the three conditions, tabulated by participants' Year of schooling. The maximum score possible for each condition is shown as '[max = *x*]'.

Table 2: Clock Drawing Test: Mean (*sd*), by condition and year of schooling

	Clock Drawing Test Condition					
			Examiner			
Year of School	**Free-drawn** [max=15]	**Pre-drawn** [max=13]	**1** [max = 11]	**2** [max = 11]	**3** [max = 11]	**N**
1	8.87 (3.74)	7.55 (2.55)	4.92 (3.35)	6.02 (2.53)	8.08 (2.97)	60
2	12.32 (2.57)	8.67 (2.51)	6.53 (3.32)	6.80 (2.84)	9.97 (1.74)	60

Given the developmental nature of clock drawing (e.g., Cohen et al, 2000; Forer et al. 1971; Dilworth et al, 2004; Springer, 1952), and the different milestones at Year 1 and Year 2 laid down in the Department for Education & Skills' National Numeracy Strategy (1998), it was predicted that across all three conditions (free-drawn, pre-drawn, examiner), the CDTs of the Year 2 participants would be more accurate (and hence higher scoring) than those of the Year 1 participants. To determine whether this was the case, a series of one-way ANOVAs and Mann-Whitney *U* Tests were carried out.

The only condition where no significant difference was found was in examiner condition 2 (time = 11:10; $F_{1,118} = 2.55, p = 0.113$). In all other conditions, year 2 participants had significantly higher scores than year 1 participants[20].

An overall CDT score for each participant was calculated by summing the scores from each condition. To help identify any anomalies, these were then extracted by various participant characteristics, the descriptive statistics from which are provided in the following table:

20 Free-drawn condition ($U = 688.00, p < 0.001$); Pre-drawn condition ($F_{1,118} = 5.85, p < 0.05$); Examiner condition 1 (time = 08:20; $U = 1275.50, p < 0.01$); Examiner condition 3 (time = 3:00; $U = 967.00, p < 0.01$); Overall examiner condition i.e., summed examiner conditions ($F_{1,118} = 11.89, p < 0.005$).

Table 3: Descriptive Statistics for Clock Drawing Test scores, by participant characteristic

Participant Characteristic	Clock Drawing Test Scores (max possible score = 61) Mean	Sd	Range	N
Female	39.09	12.00	(0 – 59)	66
Male	40.80	10.80	(17 - 58)	54
Year 1	35.43	11.47	(0 – 50)	60
Year 2	44.28	9.67	(20 - 59)	60
Without SN*	45.39	7.67	(28 - 59)	46
With SN*	36.42	12.11	(0 – 56)	74
SN**				
0	45.39	7.67	(28 - 59)	46
1	39.20	10.20	(20 - 56)	30
2	35.78	13.13	(0 – 52)	32
3	31.17	12.65	(11 - 56)	12
Average	39.86	11.46	(0 – 59)	120

* Special Needs. The 'without SN' versus 'with SN' is a dichotomous comparison of participants without special needs (category 0) against those with special needs (participants in categories 1-3).

** Special Needs Categories. 0 refers to participants with no special needs; a special needs category of 1 refers to participants whose special needs have been assessed as being addressed by the teacher; special needs categories of 2 and 3 refer to participants whose needs are partly met by the Local Education Authority.

To determine if there were any significant differences in participants' scores by these different characteristics, a series of one-way ANOVAs were performed.

Although some studies have reported a male advantage for tests involving spatial visualisation (Manger and Eikeland, 1998), it was predicted there would be no gender differences in overall CDT scores given that this is the case in most CDT studies (Ferruci et al, 1996), including that of Freedman et al (1994). This was supported - there was no significant differences between females and males in their overall CDT scores ($F_{1,118} = 0.66, p =$ ns).

The significantly higher scores of Year 2 and Year 1 found separately in each of the conditions (with the exception of examiner condition 2) was carried through in the summed CDT scores ($F_{1,118} = 20.88, p < 0.001$).

No specific predictions were made in relation to the CDT scores of participants with and without special needs status even though a significant difference has been found in a previous study (see Forer et al, 1971). A Mann-Whitney U test revealed significant differences between participants who had no special needs and participants with special needs in CDT scores ($U = 925.00, p < 0.001$). A Kruskal-Wallis one-way ANOVA revealed significant differences in CDT scores according to participants' special needs status ($x^2 = 20.80$, $df = 3$, $p < 0.001$).

4.2 Anchoring

Anchoring is a possible planning aid and involves the drawing of the digits at the 90-degree positions first (i.e., 12, 3, 6, 9). In the current study, it was only possible in the free- and pre-drawn conditions. Anchoring was decided on the basis of whether a participant drew in the anchor numbers first, irrespective of the order that they were drawn in. It was identified from the video-tape recordings made of participants when completing the test.

Overall, 113 participants completed sufficient aspects of the free-drawn condition for an anchoring decision to be made (i.e., the participant drew some type of clock contour and drew in at least one number); in the pre-drawn condition, there were 116 participants. The following two tables show the overall CDT scores for participants who anchored and those that did not, by various characteristics in the free-drawn and pre-drawn conditions.

Table 4: Clock Drawing Test scores (Free-drawn condition) by whether participant anchored or not

	Anchored			Not anchored		
	Mean	***sd***	**n**	**Mean**	***sd***	**n**
Female	46.10	7.98	10	39.73	9.77	51
Male	47.50	4.20	4	40.23	11.00	48
Year 1	48.00	-	1	36.89	9.44	53
Year 2	52.00	7.24	13	43.52	10.27	46
Without SN*	46.27	7.59	11	45.11	7.78	35
With SN*	47.33	5.13	3	37.16	10.52	64
SN**						
0	46.27	7.59	11	45.11	7.78	35
1	53.00	-	1	38.32	9.98	28
2	44.50	2.12	2	37.38	10.56	26
3	-	-	0	33.30	12.05	10
Average	46.50	6.97	14	39.97	10.33	99

* Special Needs. The 'without SN' versus 'with SN' is a dichotomous comparison of those without special needs (category 0) against those with special needs (participants in categories 1-3).

** Special Needs Categories. 0 refers to participants with no special needs; a special needs category of 1 refers to participants whose special needs have been assessed as being addressed by the teacher; special needs categories of 2 and 3 refer to participants whose needs are partly met by the Local Education Authority.

As Table 4 shows, of the 113 participants who completed sufficient aspects of the free-drawn condition, 88% did not anchor. However, there were some noteworthy differences. For example, more than double the proportion of females anchored than males; participants in year 2 accounted for all but one anchored drawing. Nearly four times as many participants without special needs anchored than with special needs, and of those with special needs, nobody with Level 3 special needs anchored.

Given the findings of Cohen et al (2000) and Ishiai et al (1993), it was predicted that more accurate clocks (and hence higher scoring) would result from anchoring. This was found - there was a significant difference in the overall CDT scores of participants who anchored in the free-drawn condition and those that did not ($F_{1,111} = 5.23$, $p < 0.05$).

Table 5: Clock Drawing Test scores (Pre-drawn condition) by whether participant anchored or not

	Anchored			Did not anchor		
	Mean	**sd**	**N**	**Mean**	**sd**	**N**
Female	47.60	8.71	10	38.42	10.60	53
Male	49.67	3.51	3	40.04	10.85	50
Year 1	-	-	-	36.11	10.32	57
Year 2	48.08	7.73	13	43.04	9.98	46
Without SN*	48.11	9.08	9	44.73	7.27	37
With SN*	48.00	4.40	4	36.11	11.10	66
SN**						
0	48.11	9.08	9	44.73	7.27	37
1	53.00	-	1	38.32	9.98	28
2	46.33	3.51	3	36.00	11.18	26
3	-	-	-	31.17	12.65	12
Average			13	39.70	10.70	

* Special Needs. The 'without SN' versus 'with SN' is a dichotomous comparison of those without special needs (category 0) against those with special needs (participants in categories 1-3).

** Special Needs Categories. 0 refers to participants with no special needs; a special needs category of 1 refers to participants whose special needs have been assessed as being addressed by the teacher; special needs categories of 2 and 3 refer to participants whose needs are partly met by the Local Education Authority.

As can be seen in Table 5, of the 116 participants who completed sufficient aspects of the pre-drawn condition, 89% (103) did not anchor. Analogous to the free-condition, there were some noteworthy differences between the participants. For example, more than three times as many females than males anchored their drawings; all anchoring was undertaken by participants in year 2; over double the number of participants with no special needs anchored compared with participants with special needs, and as with the free-drawn condition, no participant classed as Level 3 special needs undertook anchoring.

As with the free-drawn condition, it was predicted there would be a significant difference between the scores of participants that did anchor and those that did not; again, this was found ($F_{1,114} = 8.36$, p <0.005).

4.3 NORMATIVE DATA

In the following tables, the scoring of participants' drawings against the criteria of Freedman et al (1994) is provided. The achieved *n* which is shown (in brackets) for each scoring item is the denominator on which the proportion is calculated. It is the sum of participants who drew sufficient aspects of their drawings for an error to be committed i.e., it excludes refusals. For example, in the free-drawn condition, four participants from Year 1 refused to draw a contour. The achieved *n* for 'acceptable contour drawn' was 56, i.e., 60 - 4.

Table 6: Free-drawn condition (time = 6:45) - Proportion of participants who satisfied the scoring criteria for clock attributes, by Year of participant (achieved *n* in brackets)

		Year 1	Year 2
N		60	60
Contour			
	Acceptable contour drawn	63% (56)	68% (60)
	Contour is not too small nor overdrawn nor reproduced repeatedly	84% (55)	100% (60)
Numbers			
	Only numbers 1-12 (without adding extra numbers or omitting numbers)	78% (55)	90% (60)
	Arabic number representation	98% (55)	100% (60)
	Numbers written in the correct order	89% (55)	97% (60)
	Paper not rotated while drawing numbers	89% (55)	87% (60)
	Numbers in the correct position	24% (55)	28% (60)
	All numbers located inside contour	93% (55)	100% (60)
Hands			
	Clock has 2 hands/or marks	55% (55)	90% (59)
	Hour target number indicated in some manner	73% (55)	93% (59)
	Minute target number indicated in some manner	5% (55)	46% (59)
	Hands in correct proportion (minute hand longer)	16% (55)	64% (59)
	No superfluous markings	69% (55)	85% (59)
	Hands are joined or within 12mm (1/2 inch) of joining	67% (55)	92% (59)
Center			
	Clock has a center (drawn or inferred/extrapolated at the point where 2 hands meet)	71% (55)	88% (60)

Table 7: Pre-drawn condition (time = 6:05) - Proportion of participants who satisfied the scoring criteria for clock attributes, by Year of participant (achieved *n* in brackets)

		Year 1	Year 2
N		60	60
Numbers			
	Only numbers 1-12 (without adding extra numbers or omitting numbers)	83% (59)	90% (60)
	Arabic number representation	100% (59)	100% (60)
	Numbers written in the correct order	98% (59)	98% (60)
	Paper not rotated while drawing numbers	75% (59)	88% (60)
	Numbers in the correct position	2% (59)	17% (60)
	All numbers located inside contour	100% (59)	100% (60)
Hands			
	Clock has 2 hands/or marks	81% (48)	94% (48)
	Hour target number indicated in some manner	77% (48)	75% (48)
	Minute target number indicated in some manner	2% (48)	19% (48)
	Hands in correct proportion (minute hand longer)	8% (48)	38% (48)
	No superfluous markings	92% (48)	96% (48)
	Hands are joined or within 12mm (1/2 inch) of joining	83% (48)	94% (48)
Center			
	Clock has a center (drawn or inferred/extrapolated at the point where 2 hands meet)	75% (59)	80% (60)

Table 8: Examiner condition 1 (time = 11:10) - Proportion of participants who satisfied the scoring criteria for clock attributes, by Year of participant (achieved *n* in brackets)

		Year 1	Year 2
N		60	60
Hands			
	Clock has 2 hands/or marks	63% (54)	88% (51)
	Hour target number indicated in some manner	74% (54)	71% (51)
	Minute target number indicated in some manner	7% (54)	31% (51)
	Hands in correct proportion (minute hand longer)	26% (54)	35% (51)
	Hour hand/mark is displaced from hour target number within limits set by normative data (-3 to 3 degrees)	63% (54)	61% (51)
	Minute hand/mark is displaced from minute target number within limits set by normative data (-3 to 3 degrees)	6% (54)	24% (51)
	No superfluous markings	83% (54)	92% (51)
	Hands are joined or within 12mm (1/2 inch) of joining	59% (54)	88% (51)
Center			
	Clock has a center (drawn or inferred/extrapolated at the point where 2 hands meet)	70% (54)	94% (51)
	Center is displaced from the vertical axis within 5.0mm (3/16 inch) to the right or left of the axis	59% (54)	86% (51)
	Center is displaced from the horizontal axis within 5.0mm (3/16 inch) below the axis or 7.0mm (5/16 inch) above the axis	48% (54)	80% (51)

Table 9: Examiner condition 2 (time = 8:20) - Proportion of participants who satisfied the scoring criteria for clock attributes, by Year of participant (achieved *n* in brackets)

		Year 1	**Year 2**
N		60	60
Hands			
	Clock has 2 hands/or marks	81% (57)	88% (58)
	Hour target number indicated in some manner	82% (57)	67% (58)
	Minute target number indicated in some manner	2% (57)	24% (58)
	Hands in correct proportion (minute hand longer)	19% (57)	34% (58)
	Hour hand/mark is displaced from hour target number within limits set by normative data (-3 to 3 degrees)	68% (57)	59% (58)
	Minute hand/mark is displaced from minute target number within limits set by normative data (-3 to 3 degrees)	2% (57)	10% (58)
	No superfluous markings	82% (57)	86% (58)
	Hands are joined or within 12mm (1/2 inch) of joining	82% (57)	88% (58)
Center			
	Clock has a center (drawn or inferred/extrapolated at the point where 2 hands meet)	82% (57)	90% (58)
	Center is displaced from the vertical axis within 5.0mm (3/16 inch) to the right or left of the axis	58% (57)	76% (58)
	Center is displaced from the horizontal axis within 5.0mm (3/16 inch) below the axis or 7.0mm (5/16 inch) above the axis	61% (57)	81% (58)

Table 10: Examiner condition 3 (time = 3:00) - Proportion of participants who satisfied the scoring criteria for clock attributes, by Year of participant (achieved *n* in brackets)

		Year 1	**Year 2**
N		60	60
Hands			
	Clock has 2 hands/or marks	71% (59)	92% (60)
	Hour target number indicated in some manner	98% (59)	98% (60)
	Minute target number indicated in some manner	81% (59)	93% (60)
	Hands in correct proportion (minute hand longer)	20% (59)	70% (60)
	Hour hand/mark is displaced from hour target number within limits set by normative data (-3 to 3 degrees)	93% (59)	92% (60)
	Minute hand/mark is displaced from minute target number within limits set by normative data (-3 to 3 degrees)	81% (59)	93% (60)
	No superfluous markings	93% (59)	98% (60)
	Hands are joined or within 12mm (1/2 inch) of joining	69% (59)	90% (60)
Center			
	Clock has a center (drawn or inferred/extrapolated at the point where 2 hands meet)	78% (59)	93% (60)
	Center is displaced from the vertical axis within 5.0mm (3/16 inch) to the right or left of the axis	66% (59)	85% (60)
	Center is displaced from the horizontal axis within 5.0mm (3/16 inch) below the axis or 7.0mm (5/16 inch) above the axis	69% (59)	92% (60)

4.4 ERROR CLASSIFICATIONS

Errors identified in adult CDT studies suggest they can be loosely classified against four main categories – neglect, perseveration, digits, and hand placement. The scoring of the data against the criteria of Freedman et al (1994) provided for the identification of digit errors and hand placement errors. It did not however, provide for the identification of neglect and perseveration errors. Given that one of the aims of the current study involved analysing the data against these four error classifications, there was a need to adopt and apply definitions of 'neglect' and 'perseveration'.

Neglect was only possible in the free-drawn and pre-drawn conditions[21]. The definition adopted in the current study was that commonly used in the adult literature (see Ishiai et al, 1993), i.e., all 12 numbers drawn in the first two quadrants (left hemispatial neglect) or all 12 numbers drawn in quadrants three and four (right hemispatial neglect). This meant that when examining the drawings for evidence of neglect, any free-drawn or pre-drawn drawings that had less than 12 numbers were immediately discarded. The following two figures provide examples of neglect found in the pre-drawn condition.

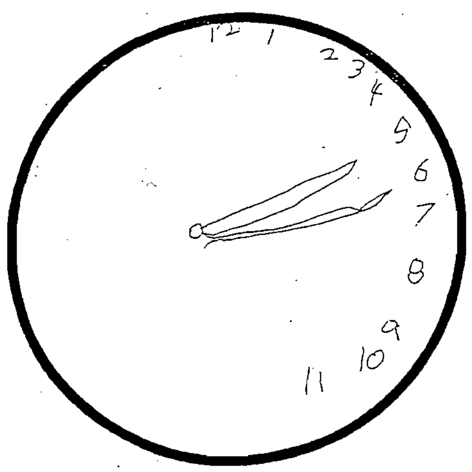


Figure 1: Example of left hemispatial neglect in pre-drawn condition (Female, Year 1) (not actual size)

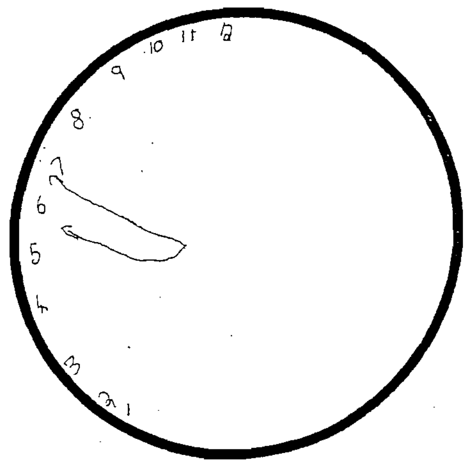


Figure 2: Example of right hemispatial neglect in pre-drawn condition (Female, Year 2) (not actual size)

21 Strictly speaking, it was also possible to make neglect errors in the examiner condition by incorrectly locating both clock hands in one hemispace. However, isolating this as neglect distinct from e.g., 'guesses', 'incorrect transcoding', was not possible given the methodology employed.

Perseveration is the continuation or recurrence of activity without an appropriate stimulus and tends to be evidenced in clock drawings through either drawing more than two clock hands or by writing beyond 12. It was therefore possible to commit perseveration errors in all three conditions, though the scope in the examiner condition was restricted to drawing more than two clock hands. This was the definition adopted in the current study. The following figure provides an example of perseveration found in the current study.

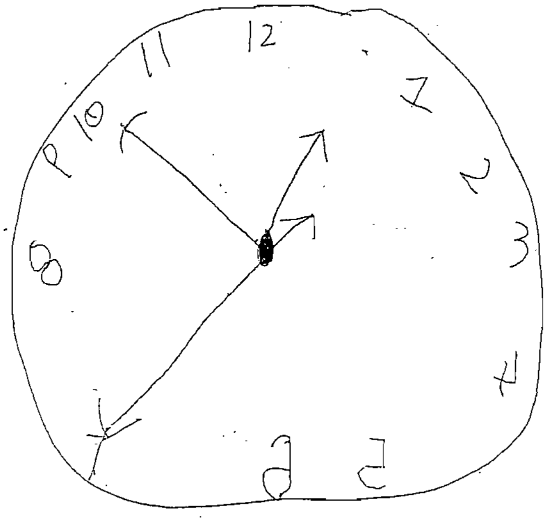


Figure 3: Example of perseveration of hands in free-drawn condition (Male, Year 1) (not actual size)

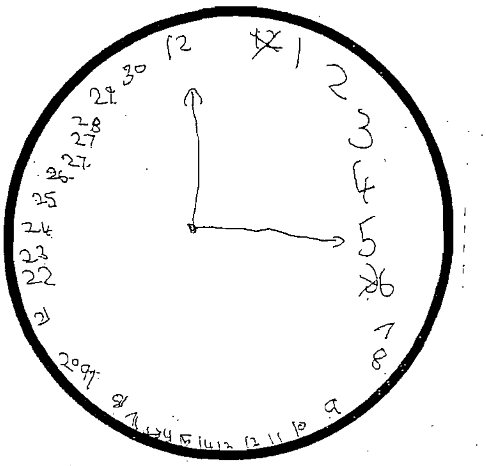


Figure 4: Example of perseveration of numbers in pre-drawn condition (Male, Year 2) (not actual size)

Overall, 115 participants had attempted sufficient aspects of the free-drawn condition and 119 participants in the pre-drawn condition to allow a possible identification of perseveration/neglect errors. The remaining participants either made no attempt or there were insufficient aspects of their drawings to be classified, e.g., drawing only a clock contour; marking a clock centre.

The number of participants who satisfied sufficient aspects of the conditions for hand placement and digit errors to be made (as derived from the scoring items of Freedman et al, 1994, shown in Tables 6-10), varied considerably between condition. In the free-drawn condition, 114 participants completed sufficient aspects for hand-placement errors to be committed; in the pre-drawn condition, there were 96; in the examiner conditions: 105 (time = 11:10); 115 (time = 8:20), and 119 (time = 3:00).

In the free-drawn condition, 115 participants completed sufficient aspects for digit errors to be committed; in the pre-drawn condition there were 119. (No digit errors were possible in the examiner condition.)

In the following sections, details about frequency of errors found in each of the four errors (perseveration, neglect, hand placement, digits) are provided.

a) Perseveration

There were 9 participants whose drawings exhibited signs of perseveration in the free-drawn condition (i.e., 8% of free-drawn drawings that were classifiable), and 9 participants in the pre-drawn condition (i.e. 8% of pre-drawn drawings that were classifiable). Further analyses revealed that 8 of the 9 participants in the free-drawn condition who made perseveration errors also made perseveration errors in the pre-drawn condition. Likewise, 8 of the 9 participants who made perseveration errors in the pre-drawn condition also made perseveration errors in the free-drawn condition.

There was a higher incidence of perseveration among Year 1 participants than Year 2 participants - in both the free-drawn condition and in the pre-drawn condition, 6 drawings from Year 1 participants (11%) and 3 drawings (5%) from Year 2 participants had evidence of perseveration.

Males and females were both likely to commit perseveration errors - (both conditions = 5 males, 4 females).

All 9 cases of perseveration in each of the two conditions were committed by participants with special needs. Participants classed as having category 1 special needs (i.e., assessed as being addressed by the teacher), made fewer perseveration errors (free-drawn = 1; pre-drawn = 1) than participants classed as having category 2 and category 3 special needs i.e., whose needs are partly met by the Local Education Authority (free-drawn = 8; pre-drawn = 8). Overall, 18% of participants classed as having category 2 or category 3 special needs committed perseveration errors compared with 3% of participants with category 1 special needs.

b) Neglect

There were 10 participants whose drawings exhibited signs of neglect in the free-drawn condition (i.e., 9% of free-drawn drawings that were classifiable), and 20 participants in the pre-drawn condition (i.e., 17% of pre-drawn drawings that were classifiable). Further analyses revealed that 7 of the 10 participants in the free-drawn condition who made neglect errors also made neglect errors in the pre-drawn condition; 11 participants who committed no neglect errors in the free-drawn condition committed neglect errors in the pre-drawn condition; 3 participants who committed neglect errors in the free-drawn condition also committed neglect errors in the pre-drawn condition.

There were 18 drawings that showed evidence of left hemispatial neglect and 12 with right hemispatial neglect.

A more robust definition of neglect was adopted than found in some studies. For example, in their study Cohen et al (2000) defined neglect as 'not using a quadrant of space'. Using this definition in the current study would have been problematic given the difficulties in isolating neglect as an error distinct from that of poor planning. Indeed, according to Ishiai et al (1993), some patients who demonstrate typical left unilateral spatial neglect in other tests, show no or only slight neglect in clock drawing, which would seem to suggest a planning deficit.

There was a higher incidence of neglect among Year 1 participants than Year 2 participants - in both the free-drawn condition and in the pre-drawn condition, 6 drawings from Year 1 participants (11%) and 4 drawings (7%) from Year 2 participants had evidence of neglect.

Females were more likely to commit neglect errors in the free-drawn condition (7 drawings or 11% of drawings by females in this condition) than males (3 drawings or 6% of all drawings by males in this condition). In the pre-drawn condition, there was gender parity (10 drawings each) but proportionately, males were more likely to commit neglect errors (19%) than females (15%).

Some 60% of free-drawn neglect errors (6 drawings) were committed by participants with special needs. Of the 10 drawings that had neglect errors, 3 were by participants with category 1 special needs (30%), 3 were by participants with category 2 special needs (30%), and 4 were by participants with no special needs (40%).

c) Clock Hands

As participants were required to set the time in all three conditions, hand errors were possible in all three conditions. The scoring criteria of Freedman et al (1994) provides for 6 different types of error in the free-drawn and pre-drawn conditions:

1) 'Clock has 2 hands/or marks'
2) Hour target number indicated in some manner
3) Minute target number indicated in some manner
4) Hands in correct proportion (minute hand longer)
5) No superfluous markings
6) Hands are joined or within 12mm (½ inch) of joining

and two additional items in the examiner conditions:

7) Hour hand/mark is displaced from hour target number within limits set by normative data (-3 to +3 degrees)
8) Minute hand/mark is displaced from minute target number within limits set by normative data (-3 to +3 degrees)

With the exception of examiner condition 3 (time = 3:00), of all 6 scoring items common across the three conditions, the item attracting the greatest frequency of errors was 'Minute target number indicated in some manner' - in the free-drawn condition, 95% of participants in Year 1 and 54% in Year 2 committed errors on this item. In the pre-drawn condition, these increased to 98% (Year 1) and 81% (Year 2). In the first examiner condition (time = 11:10), 93% in Year 1 and 69% in Year 2 committed errors on this item; in the second examiner condition (time = 8:20), 98% in Year 1 and 76% in Year 2 committed errors on this item.

In the third examiner task (time = 3:00), 19% (Year 1) and 7% (Year 2) committed errors on this item – the item attracting the most error in this task was 'hands in correct proportion (minute hand longer)' with 80% of Year 1 participants making an error and 30% of Year 2.

There were differences between participants in Year 1 and Year 2 in terms of which items attracted the greatest frequency of errors. In the following tables, the hand placement items are shown for each condition and are arranged in the order of difficulty (where the first item attracted the highest frequency of errors)

Table 11: Hand Placement scoring items ordered by frequency of errors (greatest to lowest) (Free-drawn condition)

Year 1	Year 2
Minute target number indicated in some manner	Minute target number indicated in some manner
Hands in correct proportion (minute hand longer)	Hands in correct proportion (minute hand longer)
Clock has 2 hands/or marks	No superfluous markings
Hands are joined or within 12mm (½ inch of joining)	Clock has 2 hands/or marks
No superfluous markings	Hands are joined or within 12mm (½ inch of joining)
Hour target number indicated in some manner	Hour target number indicated in some manner

Table 12: Hand Placement scoring items ordered by frequency of errors (greatest to lowest) (Pre-drawn condition)

Year 1	Year 2
Minute target number indicated in some manner	Minute target number indicated in some manner
Hands in correct proportion (minute hand longer)	Hands in correct proportion (minute hand longer)
Hour target number indicated in some manner	Hour target number indicated in some manner
Clock has 2 hands/or marks	Clock has 2 hands/or marks[1]
Hands are joined or within 12mm (½ inch of joining)	Hands are joined or within 12mm (½ inch of joining)[1]
No superfluous markings	No superfluous markings

Notes:

1 The scoring items ranked 4 and 5 had the same proportion of errors (6%)

Table 13: Hand Placement scoring items ordered by frequency of errors (greatest to lowest) (Examiner condition 1 time = 11:10)

	Year 1	Year 2
1	Minute hand/mark is displaced from minute target number within limits set by normative data (-3 to 3 degrees)	Minute hand/mark is displaced from minute target number within limits set by normative data (-3 to 3 degrees)
2	Minute target number indicated in some manner	Minute target number indicated in some manner
3	Hands in correct proportion (minute hand longer)	Hands in correct proportion (minute hand longer)
4	Hands are joined or within 12mm (½ inch of joining)	Hour target/mark is displaced from hour target number within limits set by normative data (-3 to 3 degrees)
5	Hour target/mark is displaced from hour target number within limits set by normative data (-3 to 3 degrees)[1]	Hour target number indicated in some manner
6	Clock has 2 hands/or marks[1]	Clock has 2 hands/or marks[2]
7	Hour target number indicated in some manner	Hands are joined or within 12mm (½ inch of joining)[2]
8	No superfluous markings	No superfluous markings

Notes:

1 The scoring items ranked 5 and 6 had the same proportion of errors (37%)

2 The scoring items ranked 6 and 7 had the same proportion of errors (12%)

Table 14: Hand Placement scoring items ordered by frequency of errors (greatest to lowest) (Examiner condition 2 time = 8:20)

	Year 1	Year 2
1	Minute hand/mark is displaced from minute target number within limits set by normative data (-3 to 3 degrees)[1]	Minute hand/mark is displaced from minute target number within limits set by normative data (-3 to 3 degrees)
2	Minute target number indicated in some manner[1]	Minute target number indicated in some manner
3	Hands in correct proportion (minute hand longer)	Hands in correct proportion (minute hand longer)
4	Hour target/mark is displaced from hour target number within limits set by normative data (-3 to 3 degrees)	Hour target/mark is displaced from hour target number within limits set by normative data (-3 to 3 degrees)[1]
5	Clock has 2 hands/or marks	Hour target number indicated in some manner
6	Hour target number indicated in some manner[2]	No superfluous markings
7	No superfluous markings[2]	Clock has 2 hands/or marks[3]
8	Hands are joined or within 12mm (½ inch of joining)[2]	Hands are joined or within 12mm (½ inch of joining)[3]

Notes:

1 The scoring items ranked 1 and 2 had the same proportion of errors (98%)

2 The scoring items ranked 6, 7 and 8 had the same proportion of errors (18%)

3 The scoring items ranked 7 and 8 had the same proportion of errors (12%)

Table 15: Hand Placement scoring items ordered by frequency of errors (greatest to lowest) (Examiner condition 3 time = 3:00)

	Year 1	Year 2
1	Hands in correct proportion (minute hand longer)	Hands in correct proportion (minute hand longer)
2	Clock has 2 hands/or marks	Hands are joined or within 12mm (½ inch of joining)
3	Hands are joined or within 12mm (½ inch of joining)	Clock has 2 hands/or marks
4	Minute target number indicated in some manner[1]	Hour target/mark is displaced from hour target number within limits set by normative data (-3 to 3 degrees)
5	Minute hand/mark is displaced from minute target number within limits set by normative data (-3 to 3 degrees)[1]	Minute target number indicated in some manner[3]
6	Hour target/mark is displaced from hour target number within limits set by normative data (-3 to 3 degrees)[2]	Minute hand/mark is displaced from minute target number within limits set by normative data (-3 to 3 degrees)[3]
7	No superfluous markings[2]	Hour target number indicated in some manner[4]
8	Hour target number indicated in some manner	No superfluous markings[4]

Notes:

1 The scoring items ranked 4 and 5 had the same proportion of errors (19%)
2 The scoring items ranked 6 and 7 had the same proportion of errors (7%)
3 The scoring items ranked 5 and 6 had the same proportion of errors (7%)
4 The scoring items ranked 7 and 8 had the same proportion of errors (2%)

d) Digit Errors

Digit errors were only possible in the free-drawn and pre-drawn conditions (in the examiner conditions, participants were required to draw in clock hands only). The scoring criteria of Freedman et al (1994) provides for 6 different digit errors:

1) Only numbers 1-12 (without adding extra numbers or omitting numbers)
2) Arabic number representation
3) Numbers written in the correct order

4) Paper not rotated while drawing numbers
5) Numbers in the correct position
6) All numbers located inside contour

Across both conditions, the item attracting the greatest frequency of errors was 'numbers in the correct position'. In the free-drawn condition, 76% of participants in Year 1 and 72% of participants in Year 2 committed errors on this item. In the pre-drawn condition, 98% of participants in Year 1 and 83% of participants in Year 2 committed errors on this item.

There were differences between participants in Year 1 and Year 2 in terms of which items attracted the greatest frequency of errors. In the following tables, the digit items are shown for each condition and are arranged in the order of difficulty (where the first item attracted the highest frequency of errors)

Table 16: Digit scoring items ordered by frequency of errors (greatest to lowest) (Free-drawn condition)

	Year 1	Year 2
1	Numbers in the correct position	Numbers in the correct position
2	Only numbers 1-12 (without adding extra numbers or omitting numbers)	Paper not rotated while drawing numbers
3	Numbers written in the correct order[1]	Only numbers 1-12 (without adding extra numbers or omitting numbers)
4	Paper not rotated while drawing numbers[1]	Numbers written in the correct order[1]
5	All numbers located inside contour	See Note 2
6	Arabic number representation	See Note 2

Notes:

1 The scoring items ranked 3 and 4 had the same proportion of errors (11%)

2 No errors were committed on the 'Arabic number representation' or 'All numbers located inside contour' items

Table 17: Digit scoring items ordered by frequency of errors (greatest to lowest) (Pre-drawn condition)

	Year 1	Year 2
1	Numbers in the correct position	Numbers in the correct position
2	Paper not rotated while drawing numbers	Paper not rotated while drawing numbers
3	Only numbers 1-12 (without adding extra numbers or omitting numbers)	Only numbers 1-12 (without adding extra numbers or omitting numbers)
4	Numbers written in the correct order	Numbers written in the correct order
	See Note 1	See Note 1

Notes:

1 No errors were committed on the 'Arabic number representation' or 'All numbers located inside contour' items

4.5 SUMMARY

There were 120 participants in the current study, which resulted in 600 drawings from the 3 conditions to be analysed (free-drawn; pre-drawn; examiner x 3). Data was scored against the criteria of Freedman et al (1994) – each condition had a set of critical items to be scored (free-drawn = 15; pre-drawn = 13; examiner = 11). As predicted, Year 2 participants had significantly higher scores in each of the conditions (except in examiner condition 2, time = 8:20, where no difference was found).

A total CDT score was calculated by summing the scores from the three conditions, resulting in a highest possible score of 61. A series of tests based on dichotomous factors revealed:

1) no significant differences between the scores of males and females
2) significantly lower scores for participants with special needs
3) significantly higher scores for participants that anchored their drawings

5.0 DISCUSSION

This chapter examines the findings and draws out those which have direct relevance to the broad aims of the study, where were to:

1) establish normative Clock Drawing Test data for young children

2) identify the differences between this data for young children and the normative data for adults

3) ascertain which aspects of the Clock Drawing Test young children find most difficult (the findings of which could inform teachers as to which areas to concentrate on)

4) determine whether the errors made by adults in clinical settings are also those made by young children

The remainder of this chapter is organised as follows. Addressing the first three of these aims, Sections 5.1 – 5.4 look at the four main dimensions of clock drawings (contour, digits, clock hands, and clock centre). Section 5.5 examines the perseveration and neglect errors found in the study and other clocks which had similarities to those produced by brain-damaged adults, thus addressing the fourth aim of the study. Section 5.6 looks at the application of the Clock Drawing Test in the study. Section 5.7 provides a summary of the Discussion chapter before the conclusion, which is provided in 5.8. Within sections 5.1 – 5.5, any potential implications for teaching are outlined.

5.1 CONTOUR

The drawing of a clock contour was only available in the free-drawn condition. Unlike Freedman et al (1994), there were no rectangular or square clocks, although participants were less successful at drawing an acceptable contour (63% Year 1; 68% Year 2) than the normative adults in Freedman and colleagues where 100% of participants in each age group (20-90) were successful.

The vast majority of free-drawn clocks tended to be circular or oval in shape, though some did contain elaboration of nonessential details. The smallest free-drawn clock was 1.7cm across at its widest point x 1.5cm tall at its highest point. The largest was 11.7cm x 12.5cm. Given that only 63% of Year 1 and 68% of Year 2 participants drew an acceptable contour, it is probably the case that the abilities required to draw a fairly good circular contour tend to lag some of the other skills required in 'setting the clock' (e.g., Cohen et al, 2000). However, unlike many of the other dimensions, the difference in performance between Year 1 and Year 2 was less pronounced. This may suggest that during these particular age groups, development of drawing ability does not accelerate to the same extent as other skills.

One particularly interesting observation was that even drawings whose clock contours were considered unacceptable did not necessarily lead to errors being committed in the remaining parts of the free-drawn condition – many participants were still able to indicate a clock centre, draw in the numbers and hands in some of the most obscure contours. Some participants, on seeing the poor quality of their contour crossed it out and made a second attempt (allowable). Figure 5 provides some examples of contours produced.

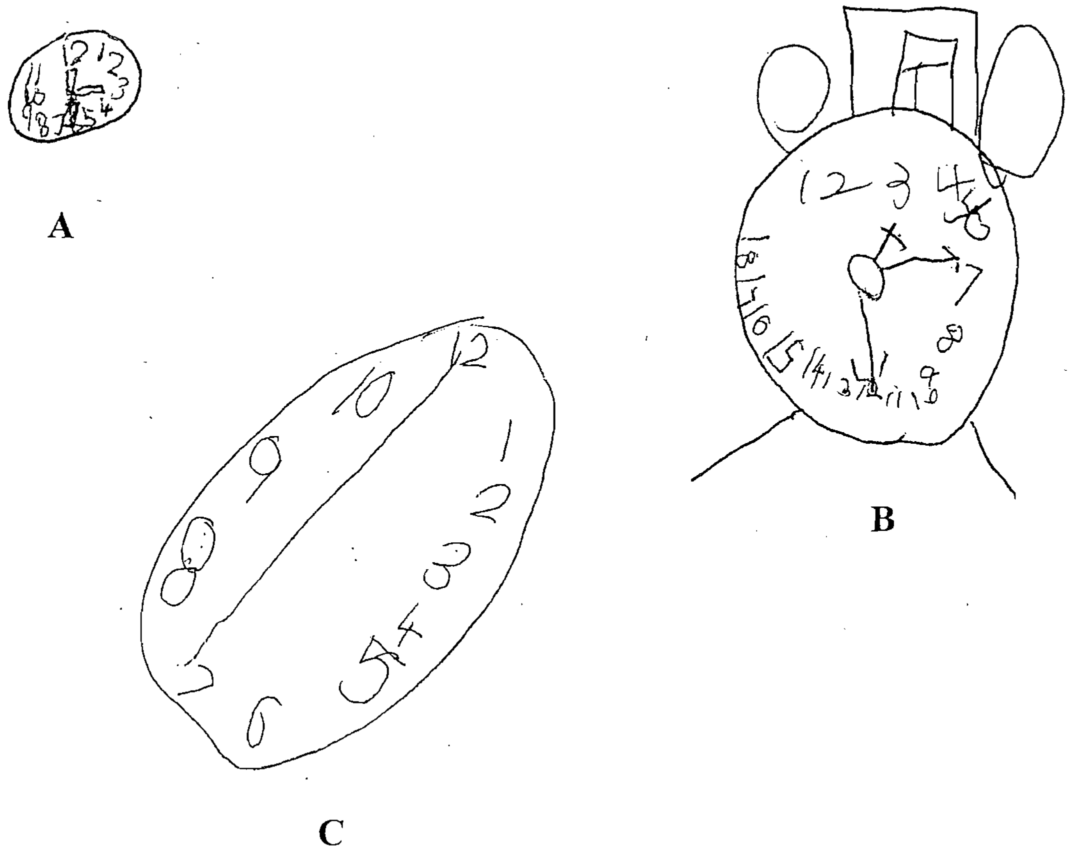


Figure 5: Examples of free-drawn clocks. (A) Smallest contour – Male Year 1. (B) Inclusion of non-essential details – Male Year 1. (C) Poor shape – Male Year 1

5.2 Digits

Digit errors were possible in the free-drawn and pre-drawn conditions only. There were some marked differences between the digit errors committed by Year 1 and Year 2 participants, and between the participants overall and those of adults from the normative data of Freedman and colleagues.

Across both conditions, all participants committed more errors in spatially locating the digits than any other digit error. This was also problematic in the normative study of Freedman and colleagues – particularly in the elderly – spatially locating digits attracted the highest error rates for the 60-69, 70-79 and 80-90 age groups.

Intuitively, a free-drawn clock should result in more digit placement errors than a pre-drawn clock, given that the latter is a perfect contour and the former imperfect (and possibly oddly shaped). This was not found in the current study; nor was this found in the normative study. Considerably more errors in digit placement were found in the pre-drawn condition (98% of drawings in Year 1; Year 2 = 83%) in the current study than the free-drawn condition (Year 1 = 76%; Year 2 = 72%). In the normative study, these differences were less pronounced but still present for the majority of age groups. For example, the 30-39 age group were error free in the free-drawn condition but had a 5% error rate in the pre-drawn condition. In the 80-90 age group, the error rates were 24% (free-drawn) and 37% (pre-drawn). In the 50-59, 60-69 and 70-79 age groups, accuracy actually increased slightly.

Overall, this was a bizarre finding and not easily explainable. Quite why a perfect contour should lead to more spatial errors in digit placement than an imperfect contour is not clear. One possibility relates to the size of the pre-drawn contour provided (11.7cm in diameter), which some participants may have found too large relative to the size of words/digits they are used to drawing. When provided with the contour, participants were faced with a decision as to how large to make the size of the digits relative to the size of contour in order to complete it accurately. Failure to make this decision and to proceed with the typical size of letters/digits they were used to producing could, for some participants, have resulted in spatial accuracy being compromised – it may also account for numerous cases of spatial neglect which were identified. In the free-drawn condition, this would not have applied to the same extent if, on average, contour size was less than 11.7cm in diameter. Although no accurate measurements were taken of each and every contour, a visual examination of all the free-drawn clocks suggests this was likely.

Although size of digit may have an impact on their spatial accuracy, it is not absolutely necessary – it is still possible to locate the digits accurately with smaller digits than the size of contour warrants. In that case the error created would not be one of the spatial accuracy of digits but would relate to the between-digits spaces created, which surprisingly does not tend to be measured in most clock drawing tests. There was some evidence of this in the current study, particularly among participants that anchored their clocks.

Anchoring in clock drawing can be considered a planning function, which if correctly undertaken reduces the scope for spatial inaccuracies in digit placement. In drawing in the 12, 3, 6 and 9 anchor digits at 90° angles it becomes easier to locate the two missing digits between each of the anchors and reduces the scope for errors from that where digits are drawn in sequence. Empirically, anchoring has been found to significantly increase clock accuracy (e.g., Cohen et al, 2000; Ishiai et al, 1993); this was also found in the current study. This has a clear implication for teachers when teaching children how to 'set the clock'. At some point, children need to be taught about anchoring – its importance in terms of accuracy, how to undertake it, why it helps, possible hints at how to remember which digits are the anchors. In doing so, this may actually assist children's spatial skills.

Overall, the most common errors for Year 2 participants remained constant between the free-drawn and pre-drawn conditions (see Tables 16-17); for Year 1 participants there was less consistency. In the free-drawn condition, the 2nd most common error for Year 1 participants was 'only numbers 1-12 without adding extra numbers or omitting numbers'; in the pre-drawn condition, this was the 3rd most common after 'Paper not rotated while drawing numbers'. Although in itself this may not appear an important, the observation that in the free-drawn condition, Year 1 participants committed 11% errors in the 'paper not rotated while drawing numbers' item but 25% in the pre-drawn condition, may be. Together with the different error rates between conditions in 'numbers in the correct position', this suggests the relationship of *contour* to other clock attributes (which are embedded within task demands) may be considerably more important than investigators think. It suggests that different findings may result (at least in terms of the spatial accuracy of digits and in terms of paper rotation) from different sizes of contour (especially if these are pre-drawn and are markedly different in size from those that would be drawn by the participant in a free-drawn condition). This also has a teaching application, that children could be taught that when planning their clocks (irrespective of whether these are free-drawn or pre-drawn), they need to consider the size of digit relative to the size of contour.

5.3 CLOCK HANDS

Errors with hands were possible across all three conditions. There were some noticeable differences between the digit errors committed by Year 1 and Year 2 participants, and between the participants overall and those of adults from the normative data of Freedman and colleagues.

Given that hand placement is the most abstract feature of clock drawing (Esteban-Santillan et al, 1998), it was not surprising to find in the current study that this attracted the highest error rate across all three conditions. Hand placement errors were also common in the normative study of Freedman et al (1994).

Worthy of note however was the difference in error rates between hour hand and minute hand placement. The former attracted error rates of between 18% (Year 1, examiner condition 2) to 33% (Year 1, free-drawn condition). In contrast, the error rates for minute hand placement were in the range 7% (Year 2, examiner condition 3 [time = 3:00]) to 98% (Year 1, pre-drawn condition; Year 1 examiner condition 2 [time = 8:20]). Although differences between hour hand placement and minute hand placement errors were to be expected (e.g., Cohen et al, 2000; Springer, 1952), given that it is the minute hand that requires abstraction (the hour hand has a concrete referent), the magnitude of these differences was highly noticeable and strongly supports the notion that Year 2 participants had a more developed 'time' vocabulary. The error rates themselves however were much higher than those found in the normative study of Freedman and colleagues. In particular, the highest error rate for the minute hand placement occurred in the free-drawn clock among the 80-90 age group (17%); there was also a noticeable increase in errors by age. Indeed, Freedman and colleagues found that the most common errors for the 70-79 and 80-90 age group (whose overall clock drawing tests scores were significantly different from all other age groups) included incorrect representation of the proportion of the hands and incorrect placement of the minute hand.

The incorrect representation of the proportion of hands also attracted errors in the current study with Year 1 participants tending to commit considerably more mistakes than Year 2 participants; there were also wide inconsistencies across conditions. In the free-drawn condition, 84% of Year 1 drawings had hand proportion errors (Year 2 = 36%); in the pre-drawn condition 92% of Year 1 drawings had hand proportion errors (Year 2 = 62%); in examiner condition 1 (time = 11:10), 74% of Year 1 drawings had errors (65% Year 2); examiner condition 2 (time = 8:20), 81% (Year 1) and 66% (Year 2); examiner condition 3 (time = 3:00), 80% (Year 1) and 30% (Year 2). It is unclear as to why 'proportion of hands' which is rule-based i.e., it requires no abstraction, would lead to such inconsistencies between conditions and within Years. One explanation may simply be a lack of awareness of the importance of hand proportions when 'setting the clock' (though in 'telling the time', they are critical). From a teaching perspective, it is clear that this rule needs to be reinforced to the same extent as it is when teaching how to 'tell the time'.

There was a similar finding of wide inconsistencies between conditions and between Years in the item 'clock has two hands/or marks'. For example, in the free-drawn condition, 37% of participants from Year 1 committed errors (Year 2 = 68%). In examiner condition 2 (time = 8:20), the proportions changed to 19% (Year 1) and 12% (Year 2). As with the proportion of hands, 'a clock has 2 hands' is rule-based. Unlike the proportion of hands however, participants were much more likely to understand that the application of this rule was absolutely necessary to the accuracy of the clock. The inconsistencies observed may be partly attributable to some participants feeling confident of the hand placement of one hand (normally the hour hand) but not feeling confident about the abstraction required for the minute hand placement, so rather than guessing, they omitted it. For other participants faced with the same issue, they may have guessed. As may be expected, the performance of the participants in the current study was considerably below that of the normative study of Freedman and colleagues where approaching 100% of all participants (with the exception of the 70+ age groups) were error free across all conditions (error rates in the 70+ age groups never exceeded 15% across all conditions).

5.4 CLOCK CENTRE

Across all three conditions used in the current study, none of the task instructions contained an explicit requirement for a clock centre to be drawn. However, in using the Freedman et al (1994) scoring criteria, measurements about the centre were required to be taken. In the free-drawn and pre-drawn conditions, this consisted of whether each 'clock has a center (drawn or inferred/extrapolated at the point where 2 hands meet)'. In the examiner conditions, more accurate measurements were taken (see e.g., Table 8).

In the free-drawn condition, 71% of Year 1 participants satisfied the scoring criteria (Year 2 = 88%); in the pre-drawn condition 75% (Year 1) satisfied the criteria (Year 2 = 80%). As may be expected, the normative adults from Freedman and colleagues were almost error free, though an age-related deterioration was apparent (especially for the 70+ age groups). However, their error rates were below those observed in the current study.

The higher error rates were also carried across in the examiner conditions, where the inaccuracies between the participants and those of normative adults were even more pronounced. In this condition, there were also marked differences in the error rates by Year. For example, in examiner condition 1 (time = 11:10), 52% of clocks from Year 1 participants erred with 'center is displaced from the horizontal axis within 5.0mm below the axis or 7.0mm above the axis'; this was 32% higher than the error rate for participants in Year 2. Similar differences were found in the other center measurements across all examiner conditions.

There is unlikely to be one parsimonious explanation that can account for these differences. One possibility is a surge in spatial skills between Year 1 and Year 2. Another possibility is more adherence to clock rules by participants in Year 2 (i.e., that clock hands meet at the centre of the clock). A further possibility is that the greater exposure to clocks/watches by participants in Year 2 enabled stronger memory representations of clockfaces, which could then be accessed (though this seems unlikely given the types of other errors committed and their frequency).

5.5 PERSEVERATION, NEGLECT AND OTHER INTERESTING CLOCKS

Although the sample were considered normative, there were a number of clocks which had remarkable similarities to those produced in other studies by clinically-based adults, in particular perseveration and neglect.

a) Perseveration

Overall, there were 12 cases of perseveration - 5 in the free-drawn condition; 7 in the pre-drawn condition. Of these, 10 were perseveration of numbers, 1 was perseveration of hands, and 1 was perseveration of hands and numbers (Figure 6). This would seem to suggest that perseveration is a normative error. If that is the case then it would seem to suggest that perseveration errors committed by adults in clock drawing is a cognitive regression, either caused by neuronal cell loss of the frontal lobes or frontal lobe dysfunction, whereas for children, perseveration is linked to the maturation of the frontal lobes. However, there were qualitative differences between the perseveration exhibited by participants in this study and those found in at least one other study, which involved adults. In particular, Rouleau et al (1996) found in their study of Alzheimer patients that many participants simply restarted the 1-12 sequence in the available space. No participants in the current study did that - all cases of perseveration (of numbers) simply continued the number sequence past 12.

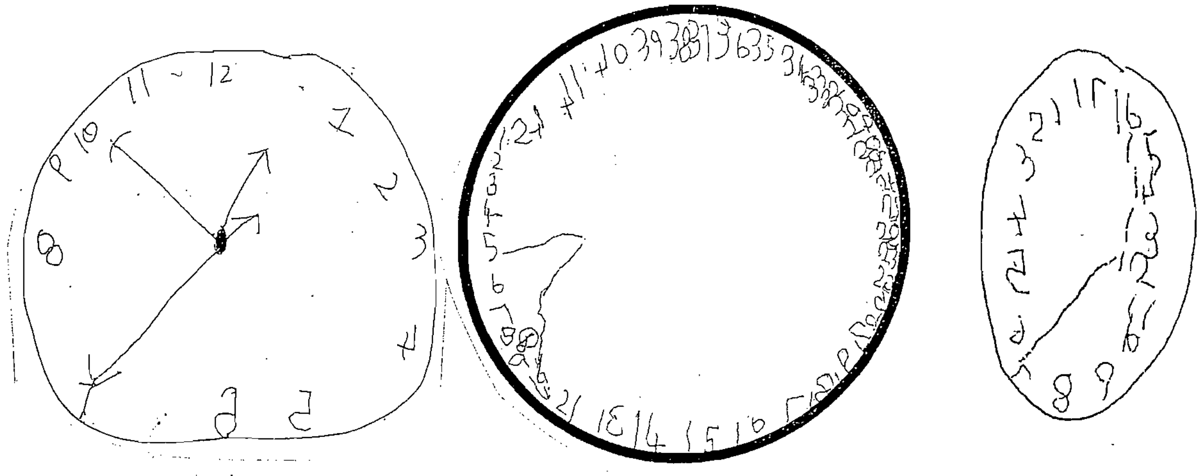
This raises an important question - what can account for the qualitative differences if maturation and regression are the root causes? One explanation may be that in the Rouleau and colleagues study, there was a conflict between the semantic knowledge that a clock only has 12 numbers and the semantic knowledge that there are no gaps in a clock contour i.e., that the numbers fill the contour, with the conflict only being resolved by applying both rules. In the current study, that conflict may not have occurred. Instead, perhaps there was no semantic knowledge (or no recall) of the 1-12 rule but there was semantic knowledge that clock contours do not have gaps. This could explain why there was such a high incidence of repeat perseveration across the free-drawn and pre-drawn conditions.

The finding that all cases of perseveration were committed by participants with special needs was unexpected and raises an important possibility that could have far reaching implications. Given that frontal lobe dysfunction is associated with perseveration and given that neuronal cell loss associated with ageing occurs prominently in the frontal lobes (Shimamura et al, 1991), and that frontal lobes do not reach maturation until age 12 (Cohen et al, 2000), it could be that for some special needs participants, the root cause of their perseveration is caused by the maturation of their frontal lobes lagging normal development. There is some support for this - there was a higher incidence of perseveration among Year 1 free-drawn and pre-drawn drawings (11%) than Year 2 drawings (5%). If this is the case then it suggests that some special needs pathology may be physiological in nature and may not be successfully addressed through educational intervention. (For this explanation to actually apply, participants would be expected to commit perseveration errors in other tests.)

However, there is also an alternative explanation - perseveration may be caused not *by* their special needs status but rather because they *have* special needs. A child with special needs is likely to lead to teachers and parents/guardians investing time addressing key omissions in abilities/knowledge/skills, which may exclude those required for 'telling the time'/'setting the clock'. In children with no special needs, the same knowledge/skills gap does not exist (at least to the same extent), meaning the impact of teachers/parents/guardians together with other extraneous experiences could lead to more advanced abilities/knowledge/skills for 'telling the time' and 'setting the clock'. This gains support from the high level of consistency observed of participants who committed perseveration errors (8 of the 9 participants in the free-drawn condition who made perseveration errors also made perseveration errors in the pre-drawn condition; 8 of the 9 participants who made perseveration errors in the pre-drawn condition also made perseveration errors in the free-drawn condition), and the finding that only 14% of Year 1 and 10% of Year 2 participants with special needs committed perseveration errors - if the root cause was wholly down to maturation of the frontal lobes lagging normal development, these proportions should have been much higher.

However, children with diagnosed special needs are heterogeneous. Whereas a physiological explanation may apply to some, it may not apply to all. Given that 'time' falls broadly within a mathematical domain, it is possible that for some special needs participants, their significantly lower CDT scores may be indicative of a more pronounced mathematical disability (MD). Support for this comes from Geary (1993) who reports that MD children suffer from a developmental delay in their counting ability[22], and also the findings of Forer et al (1971) who found in their study that Learning Disabled males had less mastery of cognitive and perceptual aspects of time understanding than normal achieving males of comparable age and IQ, and that this was a generalised rather than a specific disability i.e., they were suffering from a generalised developmental lag. This also gains further support from Dilworth et al (2004) who found that general intelligence was a significant predictor of performance on CDT copy and draw tasks but accounted for more variance in the draw condition.

22 For this argument to apply, there needs to be a relationship between counting ability, or at least some of the skills in counting (e.g., retrieval of arithmetic facts), and the skills in CDT completion. There is tentative support for this – children have been observed using counting in studies involved 'time understanding' (e.g., Springer, 1952). As a strategy, counting has also been observed in studies involving clinically-based adults in 'time-related' tasks e.g., Cipolotti and de Lacy Costello (1995). However, the case-study findings of MAR and DUV as documented in section 2.4 do not offer support to this linkage.



A B C

Figure 6: Examples of perseveration. (A) Perseveration of hands – Female Year 1 (not actual size). (B) Counterclockwise perseveration – Male Year 2 (not actual size). (C) The same participant's free-drawn clock (not actual size)

b) Neglect

Overall, 10 free-drawn and 20 pre-drawn clocks showed evidence of spatial neglect; 18 drawings showed evidence of left hemispatial neglect and 12 right hemispatial neglect (Figure 7). Analogous to perseveration, this would seem to suggest that neglect is a normative error and in clinically based adults, may represent cognitive regression or disintegration.

In some respects, it had more evidence suggesting it is a normative error than perseveration. Firstly, there was a much higher incidence - 30 drawings out of an eligible 120. Secondly, there was less consistency between conditions - the pre-drawn condition had twice the number of the free-drawn. Thirdly, the lack of consistency in committing neglect errors by participants - 47% of spatial neglect errors were peculiar to either the free-drawn or pre-drawn condition. Fourthly, and unlike perseveration, neglect errors were not wholly committed by participants with special needs - 60% of free-drawn neglect errors (6 drawings) were committed by participants with special needs and 56% (11 drawings) in the pre-drawn condition.

Together, these findings suggest there is less likelihood of neglect being physiological in nature than perseveration. Indeed, there is some debate as to whether spatial neglect is actually neuropathological or related to planning ability. For example, Rouleau et al (1996) suggest that the tendency to write all the numbers on the right hand side of the clock could be an indication of a planning deficit rather than true neglect of the left hemispace. Together with the observations that number positioning skills in clock drawing continue to develop beyond the age of 12 (Cohen et al, 2000), that planning and concentration skills are required to get spatially accurate digits (Death et al, 1993), and that left hemispatial neglect is more common that right hemispatial neglect (Martin, 1998), this explanation appears particularly parsimonious for clock drawing given that the numbers are sequential clockwise.

For some participants, this explanation may hold. Indeed, in Figure 7, a pre-drawn clock is shown which has extremely poor planning of the digits; had the participant followed the same planning for '11' as they had done for the 1-10 digits, the drawing would have certainly been classed as suffering from left hemispatial neglect. However, the observation that the '11' was almost perfect spatially would seem to suggest that poor planning and/or lack of concentration was at fault.

For other participants, neglect as a planning deficit may not hold given that only 60% of drawings with spatial neglect in the current study were left hemispatial neglect - the remaining 40% were right hemispatial neglect, which would seem to question whether one explanation is sufficient. There is a possibility, at least for some participants, that their neglect could be related to spatial acalculia, which Geary (1993) defines as difficulties in the spatial representation of numerical information. Although defined in relation to arithmetic, there are similarities to that required for the clockface. For example, misaligning numbers in multicolumn arithmetic problems (and/or place values) could be considered qualitatively similar to misaligning a digit on an analogue clock (which needs to be equidistant from the centre and from other digits). Again however, the question arises as to whether spatial acalculia has neuropathological or experiential causes or whether indeed it is in any way related to spatial neglect. It is nevertheless clear that planning remains a key component of clock drawing and of the potential for spatial neglect. For example, by its very nature, anchoring precludes the possibility of spatial neglect.

On the whole, the finding that the incidence of right and left hemispatial neglect were similar, that neglect was not peculiar to participants with special needs, that the pre-drawn condition has twice the number of neglect errors than the free-drawn condition, and that nearly half of all neglect errors were peculiar to one condition (i.e., a high proportion of participants who committed neglect errors made them in one condition only), suggests that neglect may have multiple causes and may not be a unitary error. In common with other studies and as Agrell et al (1998) point out, the value of clock drawing in assessing unilateral spatial neglect requires further investigation.

From a teaching perspective, the finding of neglect in clock drawing should be considered as possible poor planning. However, if combined with difficulties in 'telling the time' from a clock, which Martin (1998) considers evidence of possible hemispatial neglect, the probability of actual spatial neglect may be increased. The teaching of proper planning (anchoring) may be sufficient for some children; for others, clinical intervention or clinical quantification of the problem may be required.

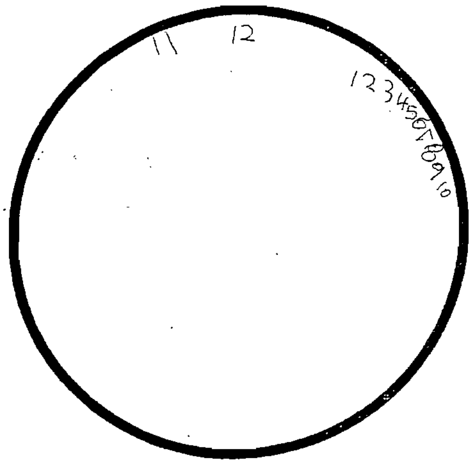


Figure 7: Example of poor planning? (Male Year 1) (not actual size)

In summary, the findings of perseveration and neglect in the current study, and the frequency with which they were found, suggests they are normative. One parsimonious explanation for their existence (at least in the current study) concerns conflict resolution - that they are the result of different outcomes from the same conflict of rules. On the one hand, there is the semantic knowledge that there are 12 digits on the clock; on the other hand, there is the semantic knowledge that digits are spatially equidistant from one another and from the clock centre and that they hug the clock contour. For some participants, marrying these two requirements together may have been problematic and may have resulted in either type of error.

It is also the case that these two errors attract more attention in many studies than other errors. This raises the question of whether this is because they have a greater visual impact than other errors such as those relating to clock hands (which actually attracts a higher frequency of errors across most studies) or whether it is because they are also tested for in other batteries. Irrespective of which reason applies, it is clear that neither constitutes the highest error rates for clock drawings.

c) Other interesting clocks

With the exception of perseveration and neglect, participant errors in the current study were locatable within the categories used in the normative study of Freedman et al (1994) e.g., clock hands, digit, contour, centre.

Freedman and colleagues also replicated their CDT among samples of dementia patients and brain-damaged patients. Although not an original aim of the current study, drawings from all three conditions were visually compared against those of dementia and brain-damaged study provided by Freedman and colleagues. Some remarkable visual similarities were identified, which covered neglect errors, perseveration errors, and other clock attributes; these spanned all three conditions.

A case of neglect and non-use of the clock contour to guide digit placement in the current study was almost the mirror image of a female aged 71 suffering from Parkinson's disease with dementia (Figure 8). In examiner condition 1 (time = 11:10), the clock hands drawn by a female aged 74 with Parkinson's disease and dementia was very similar to that of a female Year 1 from the current study (Figure 9). Both had displacement of the centre (the hands were joined near the digit '10') and both had transcoding/abstraction errors (also called stimulus-bound errors) of the '10' - instead of the minute hand pointing at the '2' indicating ten minutes past, it points to the '10' itself. In examiner condition 3 (time = 3:00), the clock hands drawn by a patient suffering from right parietal damage had remarkable similarities to that of a female Year 2 (Figure 10). Both had displacement of the centre but both nevertheless showed the correct time.

The findings that some clock drawings produced by brain damaged patients were similar to some of those made by young children was remarkable and suggests that at least for these adults, they were suffering from some type of cognitive regression or disintegration. However, there were also drawings made by the participants in the current study that appeared quite distinct from those of the clinical sample of Freedman and colleagues and from all other studies. Figure 11 shows the three examiner clocks from a female Year 1 participant. In the first examiner clock (time = 11:10), two hands are drawn but their spatial location suggests only a guess with no direct linkage to the time provided; an '11' is drawn in underneath the '12'. In the second examiner clock (time = 8:20), no attempt is made at drawing hands; instead a squiggle resembling an '8' is drawn. In the third examiner clock (time = 3:00), the two hands are drawn and are pointing correctly but there is no clock centre drawn or inferred. Figure 12 also shows the three examiner clocks from a female Year 1. Here, there is some rather bizarre usage of clock hands with the first two clocks each having two clock hands but only one in the third clock. Also, although all clock hands have arrows, none of them are pointing at the digits. Figure 13 shows the second examiner clock (time = 8:20) as drawn by a female Year 1. Here, there are two hands that breach the centre and point towards the '9' and the '8', the latter of which is also circled. It is not known whether the point at which the two hands meet (near the '2' digit) has any relevance to what the participant was attempting to convey or whether this was a drawing mistake, but given that '2' is implicated in the minutes required ('20 past'), and given the lack of any attempt at correction, it seems probable.

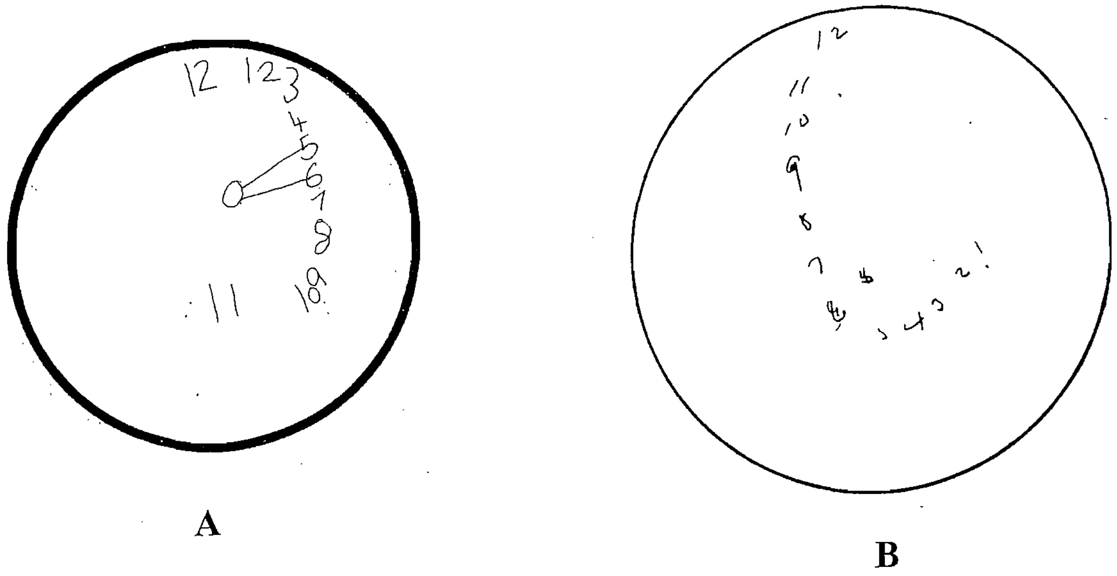


Figure 8: Pre-drawn condition. (A) Left hemispatial neglect, Female Year 1 (not actual size). (B) Female aged 71 suffering from Parkinson's disease with dementia (not actual size)[23]

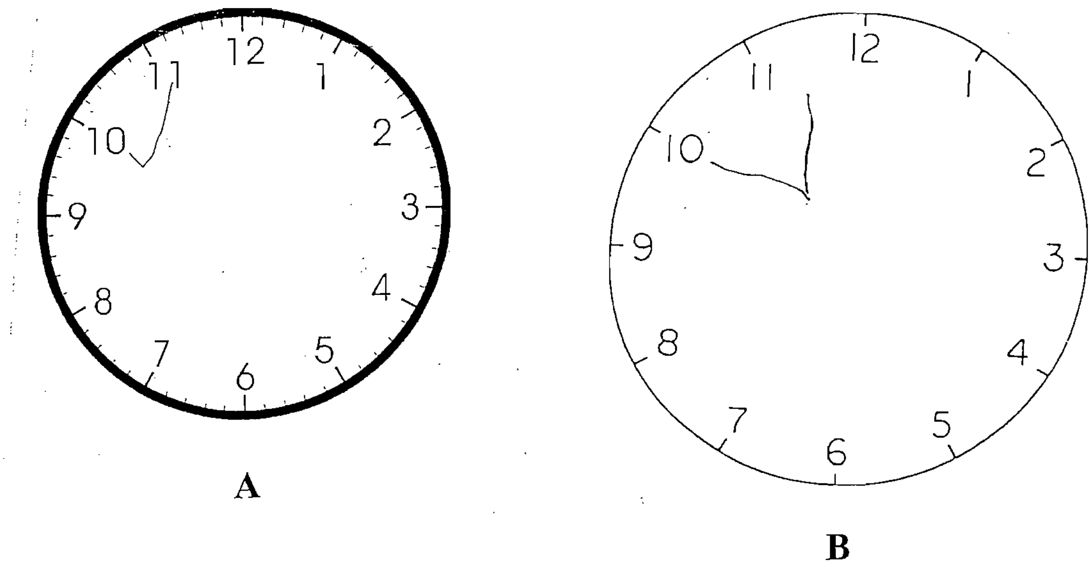


Figure 9: Examiner condition 1 (time = 11:10). (A) Female Year 1 (not actual size). (B) Female aged 74 suffering from Parkinson's disease with dementia (not actual size)[23]

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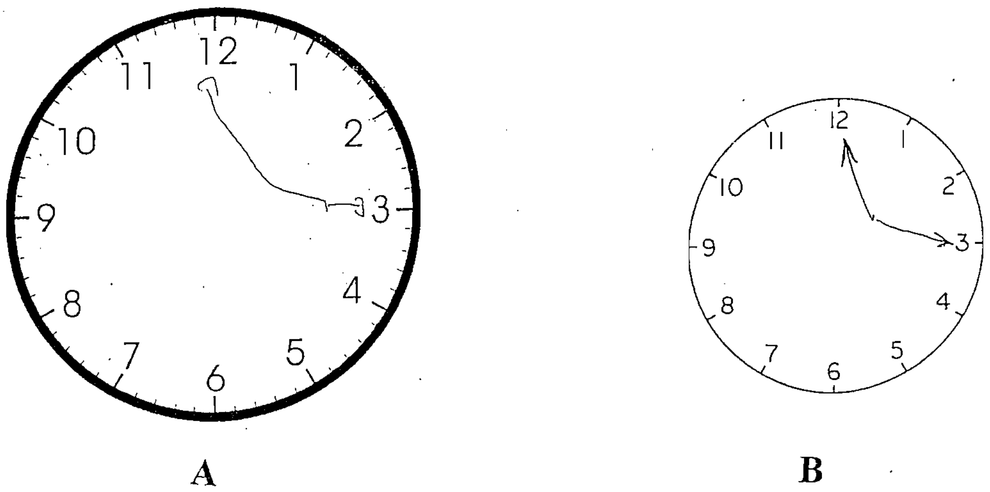

Figure 10: Examiner condition 3 (time = 3:00). (A) Female Year 2 (not actual size). (B) Patient suffering from right parietal lobe damage (not actual size)[24]

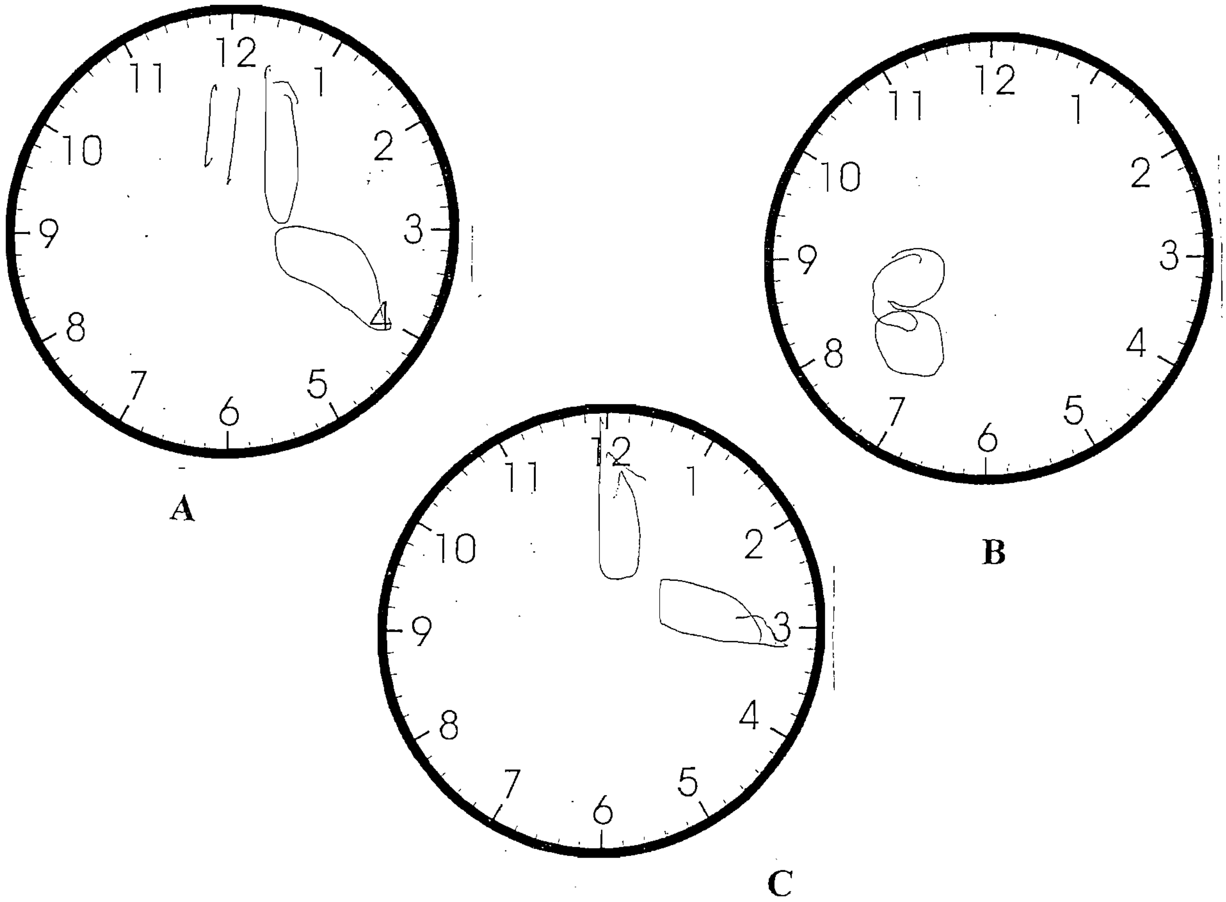

Figure 11: Examiner clocks of Female Year 1 (not actual sizes). (A) Time = 11:10. (B) Time = 8:20. (C) Time = 3:00

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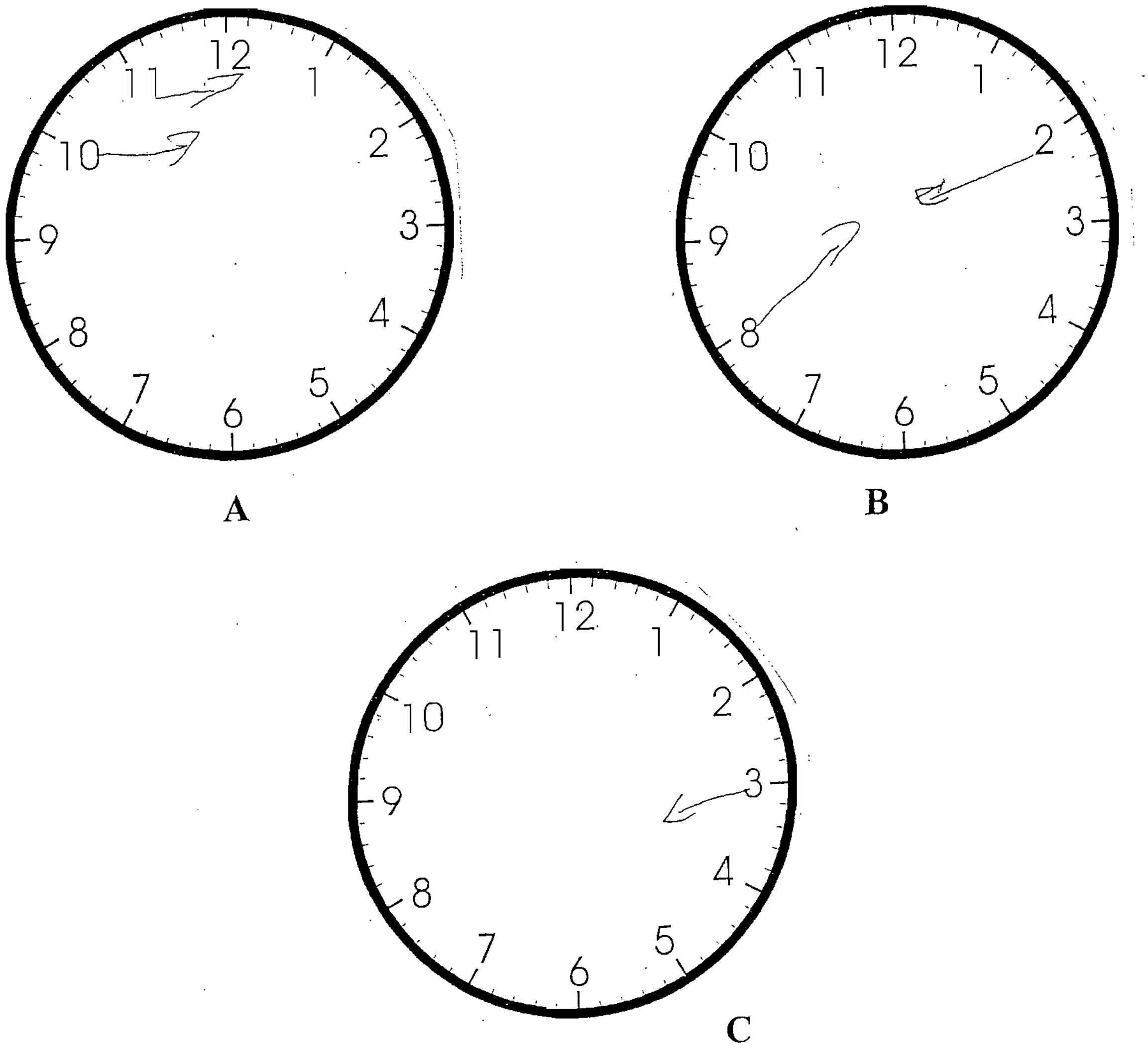

Figure 12: Examiner clocks of Female Year 1 (not actual sizes). (A) Time = 11:10. (B) Time = 8:20. (C) Time = 3:00

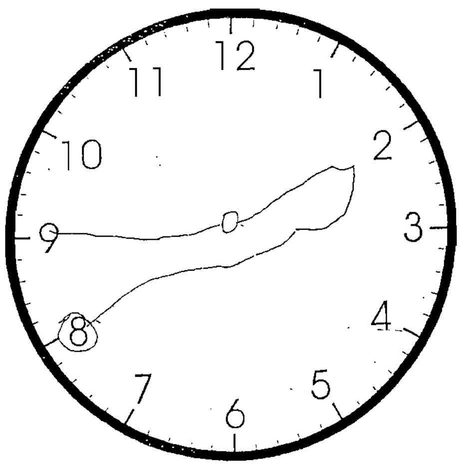

Figure 13: Examiner clock condition 2 (time = 8:20), Female Year 1 (not actual size)

5.6 THE CLOCK DRAWING TEST

This section examines some of the methodological implications and issues that arose through using the design of Freedman et al (1994).

Firstly, in using the scoring criteria of Freedman et al (1994), the current study was not concerned with developing a new scoring system, which many in the literature attempt to develop. Although there may be advantages in doing this (e.g., development of a holistic understanding of clock drawing from various angles), it does mean that comparisons tend to be restricted; interpretations can also be difficult. The study therefore contributes to a wider base of normative data. This has a number of uses. Firstly, in comparing the participants' data to those of clinical populations, it is clear that many errors committed by adults can be locatable within those undertaken during the initial learning stages of clock drawing, which may suggest cognitive disintegration or regression. Secondly, if errors are not locatable within the normative data of children then investigators will know that other cognitive and/or motor mechanisms may be at fault.

The finding from the pilot that the task instructions from the CDT were culturally biased was an important one. Had the pilot not been included in the study's design, the normative data would have shown a higher error rate than was actually the case. It also means that true international replications of the CDT in English-speaking countries may be restricted. However, there is an issue as to whether subtle changes to task instructions which are semantically identical to an original Test render comparisons and replications invalid.

Further, it is possible that the task instructions themselves constitute an effect on task success. Although the pilot usefully identified cultural bias in wording, it is possible that some of the findings could have been different had some additional controls been put in place to ensure that participants understood task instructions. For example, if there had been an actual check of some kind with each participant to determine if they fully understood the requirements of each task prior to commencing it, a need may have been identified for additional verbal guidance (especially given the age of the participants). Task success may also have been influenced by the lack of additional guidance/prompting (though their inclusion may actually confound findings). Indeed, free-drawn task success may have been higher for some participants if they had been advised at the outset to draw a circle large enough to include digits and had been forewarned that they would be required to drawn in a time once they had completed drawing the contour and digits. It is also possible that task success was lower for some participants who, on realising they had erred, did not think to ask whether they could repeat a task. This creates a methodological dilemma and raises some important questions. Firstly, can a Clock Drawing Test designed for adults be administered to young children without changes to task instructions? If remaining semantically identical, could the task instructions be varied without loss of validity? Would qualitative investigations into children's knowledge of clock time yield different data to that obtained quantitatively? These are methodological issues which could be addressed in future studies.

An obvious weakness in the study was the omission of independent raters and the lack of training in the scoring criteria (even though the criteria of Freedman et al, 1994, appear straightforward). Although the scope for bias in the scores was partially reduced by scoring all drawings prior to the special educational needs of each participant being known, the study could have been more robust had the scoring been undertaken by at least two raters and the inter-rater reliability calculated. Nevertheless, given that the CDT requires little or no experience in cognitive assessments (Lorentz, Scanlan, and Borson, 2002), and given the internal quality assurance measures that were adopted, it was considered that these omissions did not have an unduly negative impact.

One key finding which impacts on the methodology of Clock Drawing Tests concerned the consistency to which a participant who committed one type of error in the free-drawn condition also repeated it in the pre-drawn condition. Although the consistency of perseveration errors was high, for neglect it was noticeably different, and it was only possible to identify this through the inclusion of both conditions. This suggests that in other studies where the design was limited to just one condition, conclusions may have been drawn on less than satisfactory evidence. The inclusion of the free-drawn and the pre-drawn conditions were therefore justified.

However, that is not to conclude that both were easy to score. The free-drawn condition was much more difficult given that their accuracy was heavily informed by the quality of the contour. A clock size that was too small or too large, or a clock which departed from a circular shape obviously made the spatial accuracy of digits (and centre point) more difficult. As other commentators have pointed out (e.g., Freedman et al, 1994), participant-drawn circles can confound results if they are too small, irregular shape etc; they can also be difficult to score. This is probably why investigators prefer to use a pre-drawn condition. However, as Ishiai et al (1993) point out, a printed-circle may act as a cue for placing the digits on either side; in a free-drawn condition, this cue does not exist.

This leads to the issue of the error classifications used. Although replicating the scoring criteria of Freedman et al (1994), the study also observed that errors could be classed against one of four categories – perseveration, neglect, clock hands, and digits. In doing so, it provided the idea that they holistically captured the different dimensions of clock knowledge. That may not actually be the case. Clock hands errors and digit errors are necessarily peculiar to Clock Drawing Tests and reflect underlying difficulties in the representation of time. In contrast, perseveration and neglect are errors that can be committed across a number of test batteries and may reflect deficits in visual-motor skills, planning and attention. In other words, evidence of perseveration or neglect may not in itself signify a lack of knowledge of time or a lack of knowledge about the representation of time, but may instead be indicative of deficits in some of the generic skills necessary to complete a CDT task. This can be considered a fundamental difference and would seem to suggest a need to combine quantitative with qualitative lines of enquiry when designing tasks aimed at measuring skills and knowledge of time.

This need gains further support from the design of the CDT itself. Utilising clock drawing tasks with varying levels of cue-support for participants (i.e., free-drawn = no support; pre-drawn = contour support; examiner = contour and digit support), may not capture participants' underlying knowledge of time or knowledge of its representation. What these conditions may capture are the skills necessary to transpose that knowledge into a visual form. Therefore, triangulating CDTs with qualitative lines of enquiry could provide more holistic data and a better understanding of intact and impaired processing. Adding further conditions may also help. For example, a CDT task which shows a clock displaying a time and asking participants to verbally report what time is being displayed, may capture qualitatively different knowledge to that required in a task requiring the participant to draw the same time. There may also be differences between displaying that time on a digital clock and an analogue clock. Additionally, designing tasks that measure participants' knowledge of the concept of time (e.g., an egg-timer; sun-dial) may help isolate particular types of errors/knowledge.

Unlike the Freedman et al (1994) design, the current study also examined whether participants anchored their free-drawn and pre-drawn clocks, and if so whether this resulted in more accurate (and hence higher scoring) clocks. This is not a task that is routinely included in Clock Drawing Test designs but where it has been included, anchoring has been found to be significant (see Cohen et al, 2000; Ishiai et al, 1993). This would seem to suggest that in future studies, investigators pay particular attention to the process by which participants (clinical or otherwise) draw their clocks, particularly whether they anchor and whether this has any benefits to the overall accuracy.

Although the scoring criteria of Freedman et al (1994) appear robust, both in terms of how it was developed, questions remain about the validity of some of the actual criteria. In particular, in the free-drawn and pre-drawn conditions, one of the digit errors is 'paper not rotated while drawing numbers'. This is questionable as an error (particularly among adults), because no instruction is provided to participants on whether digits should be Arabic or Roman Numerals, and this impacts on whether they should be vertically-orientated (Arabic) or centripetally (Roman Numerals), the latter of which would normally require rotation of the paper when drawing. This also raises the question of whether 'Arabic number representation' should constitute a scored error item given that participants are not instructed on which type of numerals to drawn.

Finally, and although not related to the CDT itself, the consideration given to ethics and the safeguards that were designed, provided a more complete methodology that might otherwise been the case. Nevertheless, in terms of the participants themselves (and analogous to many other tests), it is not possible to discount the possibility that some participants did poorly because of poor motivation or anxiety. Without the inclusion of specific batteries to test for this, it is not clear how much impact this actually had. The absence of test-retest reliability also means it is not clear how reliable the Test is among children. A further influence on participants' results may have been their meta-memory, given that some components of meta-memory are similar to functions that have been attributed to the frontal lobes, such as planning, monitoring, and organising motor and cognitive functions (Shimamura et al, 1991). No testing of meta-memory was undertaken.

5.7 SUMMARY

When compared against normative adults, the errors committed by participants in all three conditions tended to be considerably higher, a finding that was not unexpected given the their age. However, there were some noticeable differences both between Years and between conditions. Finding that Year 1 participants committed more errors than participants in Year 2 was not unexpected as it helps clearly demonstrate a developmental progression in the abilities and knowledge required to complete the tasks. What was surprising was the lack of consistency between conditions and between Years in the application of some of the rule-based requirements, in particular, that of the correct proportion of clock hands and that a clock actually has 2 hands.

5.8 CONCLUSIONS

The acquisition of the skills and knowledge required to 'tell the time' and 'set the clock' (two distinct processes), are probably a key requirement across most of the industrialised world. As the clockface is almost universally understood, it provides investigators with a ready tool by which to test these skills and knowledge and help identify ways in which in may best be taught; it also enables investigators to identify intact and impaired abilities in clinical populations which may provide knowledge about the underlying neurocognitive structures involved.

In broad terms, this study set out to determine whether the errors in clock drawing made by adults in clinical settings were also those made by young children; it also aimed to establish robust normative data. An examination of Clock Drawing Tests (CDTs) led to the multi-design of the Freedman et al (1994) being tested to determine whether it was suitable for English children. The finding from the pilot that it was culturally-biased and required amendment to the task instructions may have been an important one as it suggests that different findings may result from different task wordings (even though these may be semantically identical). At the very least, this should make investigators cautious about simply replicating a CDT without regard to possible differences in the usage of clock vocabulary.

The CDT used in the study was arguably robust given the three conditions it employs; the use of these conditions was partly justified through the different/inconsistent findings that were found. This suggests that the findings/conclusions drawn in other studies that have used just one CDT design may actually be less robust (and in some cases, possibly erroneous). However, some of the scoring criteria itself is questionable; e.g., 'paper rotation', use of 'Arabic numerals' are not necessarily dimensions which are indicative of 'good clocks'. Indeed, clocks with Roman Numerals tend to require the paper to be rotated in order for the digits to be centripetally orientated (unlike Arabic numerals which are vertically orientated). It is probably the case that no test battery ever fully captures all dimensions of the phenomena they are designed to measure. However, it is clear from this study that the criteria of Freedman and colleagues omit several important dimensions. Firstly, cases of perseveration and neglect are not identifiable from the scoring itself. Secondly, it omits the process by which participants complete the tasks, e.g., how they plan and execute it. This suggests it may require further development in order to make it more holistic.

There were a number of findings from the main research which raised a number of questions that future research could address. Firstly, why were perseveration errors committed exclusively by participants with special needs? Was this because of lagging maturation of the frontal lobes or some other reason? If lagging maturation of the frontal lobes is implicated then are there alternative strategies that teachers could impart which utilise different neurocognitive domains? Could repeated practice of various tasks involving the frontal lobes actually speed up their maturation? If frontal lobes are not the answer then is there another neuropathological reason? Or could it be the case that special needs children are a cognitively heterogeneous group with varying aetiologies?

Secondly, some of the inconsistencies found between the error rates of the free-drawn and pre-drawn conditions suggest that contour size may be considerably more influential in certain clock attributes than currently considered (digit size and spatial accuracy of digit placement in particular). Future studies that employ variants of a pre-drawn condition could therefore examine the impact on participants' performance of different sizes of contour. Size of contour may also have been a factor in several cases of spatial neglect observed in the study. Indeed, the finding that approaching half of all cases of neglect was peculiar to each of the conditions suggests that its presence in clock drawing may not necessarily be a neurocognitive error but a planning one. In future studies, this could be looked at in relation to contour size.

One important question that arises when comparing data from children to adults is whether it has been produced using the same processes. In other words, are the processes that adults use different from those of children? For example, do adults simply access a memory representation of a clock and then reproduce it? Do children, who may not have an accessible or strong internal representation, use rules? Is accurate clock drawing a reflection of superior encoding and/or superior retrieval or simply better developed constructional abilities? These questions were not addressed in the current study as the assumption was made that the participants simply used less-developed processes than adults to complete the tasks[25]. This may not have been the case, especially given the inconsistencies between conditions in the frequencies found of the same type of error.

From a teaching perspective, there are a number of findings from the study which may be helpful when considering how best to teach children 'how to set the clock'. Firstly, the finding that participants who anchored their clocks had significantly more accurate

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25 This assumption has support from other investigators. For example, Siegler et al (1994) identify commonalities between children's processes and those of [brain-damaged] adults.

clocks than participants who did not suggests that it is a key planning function. Secondly, the issues of contour size, perseveration, neglect, and digit size all suggest that children need to be taught that when planning their clocks (irrespective of whether these are free-drawn or pre-drawn), they need to consider the size of digit relative to the size of contour. Thirdly, there appeared to be a lack of awareness of the importance of the correct clock hand proportions when 'setting the time' (a quite bizarre finding given its importance in 'telling the time'). From a teaching perspective therefore, it is clear that this rule needs to be reinforced to the same extent as it is when teaching how to 'tell the time'.

However, having stated the possible implications for teaching, it should also be noted that it cannot be left to the teacher alone to teach children how to 'tell the time' and 'set the clock'. As Andrade (1992) suggests, this should be constantly reinforced at home as well as at school. This could mean that parents/guardians would benefit from some simple teaching materials which at the very least, concentrate on those aspects children find most difficult.

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APPENDIX A

The following criteria was used to score the clock drawings and is from "CLOCK DRAWING: A NEUROPSYCHOLOGICAL ANALYSIS" by Morris Freedman Larry Leach, et al, copyright © 1994 by Oxford University Press, Inc. Used by permission of Oxford University Press, Inc."

Note: the scoring headings for each clock dimension are provided in *italics* and are not scored; the items indented under the scoring headings score 1 point if a drawing possesses that attribute or 0 (zero) points if it does not.

Free-drawn condition: Scoring Criteria

Contour

Acceptable contour drawn

Contour is not too small nor overdrawn nor reproduced repeatedly

Numbers

Only numbers 1-12 (without adding extra numbers or omitting numbers)

Arabic number representation

Numbers written in the correct order

Paper not rotated while drawing numbers

Numbers in the correct position

All numbers located inside contour

Hands

Clock has 2 hands/or marks

Hour target number indicated in some manner

Minute target number indicated in some manner

Hands in correct proportion (minute hand longer)

No superfluous markings

Hands are joined or within 12 mm (1/2 inch) of joining

Center

Clock has a center (drawn or inferred/extrapolated at the point where 2 hands meet)

Pre-drawn condition: Scoring Criteria

Numbers

Only numbers 1-12 (without adding extra numbers or omitting numbers)

Arabic number representation

Numbers written in the correct order

Paper not rotated while drawing numbers

Numbers in the correct position

All numbers located inside contour

Hands

Clock has 2 hands/or marks

Hour target number indicated in some manner

Minute target number indicated in some manner

Hands in correct proportion (minute hand longer)

No superfluous markings

Hands are joined or within 12 mm (1/2 inch) of joining

Center

Clock has a center (drawn or inferred/extrapolated at the point where 2 hands meet)

Examiner condition: Scoring Criteria

Hands

Clock has 2 hands/or marks

Hour target number indicated in some manner

Minute target number indicated in some manner

Hands in correct proportion (minute hand longer)

Hour hand/mark is displaced from hour target within limits set by normative data (-3 to 15 degrees)

Minute hand/mark is displaced from minute number within limits set by normative data (-6 to 3 degrees)

No superfluous markings on the clock

Hands are joined or within 12 mm (1/2 inch) of joining

Center

Clock has a center (drawn or inferred/extrapolated at the point where 2 hands meet)

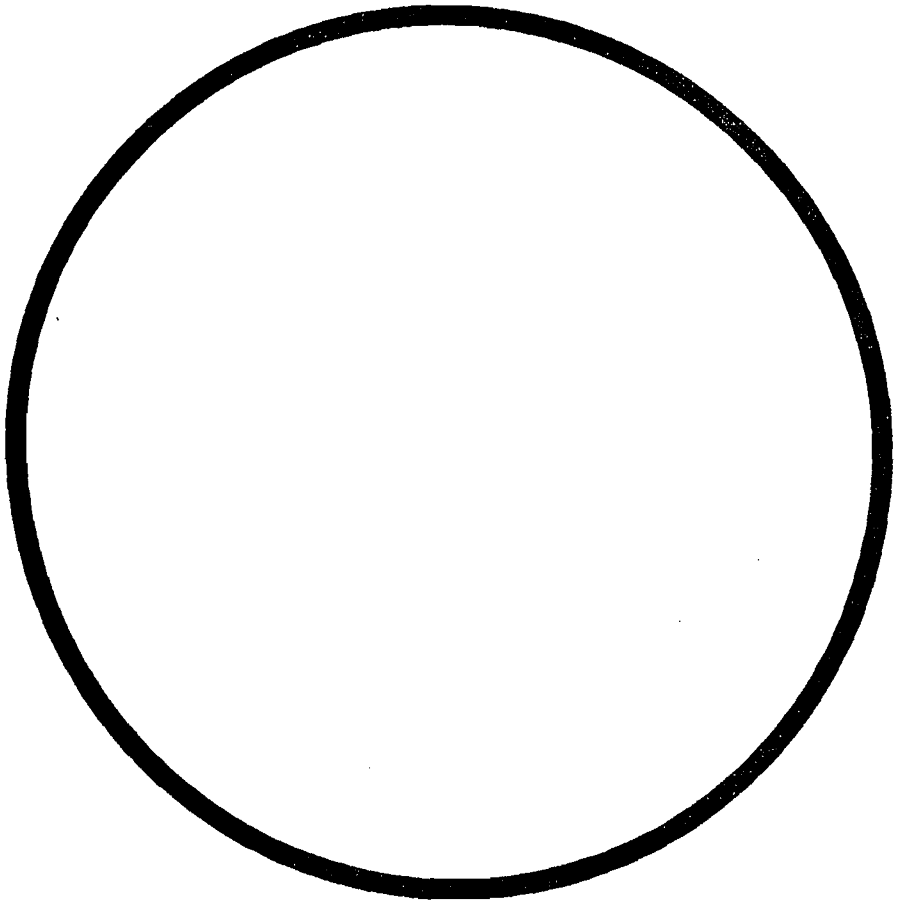
Centre is displaced from the vertical axis within 5.0mm (3/16 inch) to the right or left of the axis

Centre is displaced from the horizontal axis within 5.0mm (3/16 inch) below the axis or 7.0mm (5/16 inch) above the axis

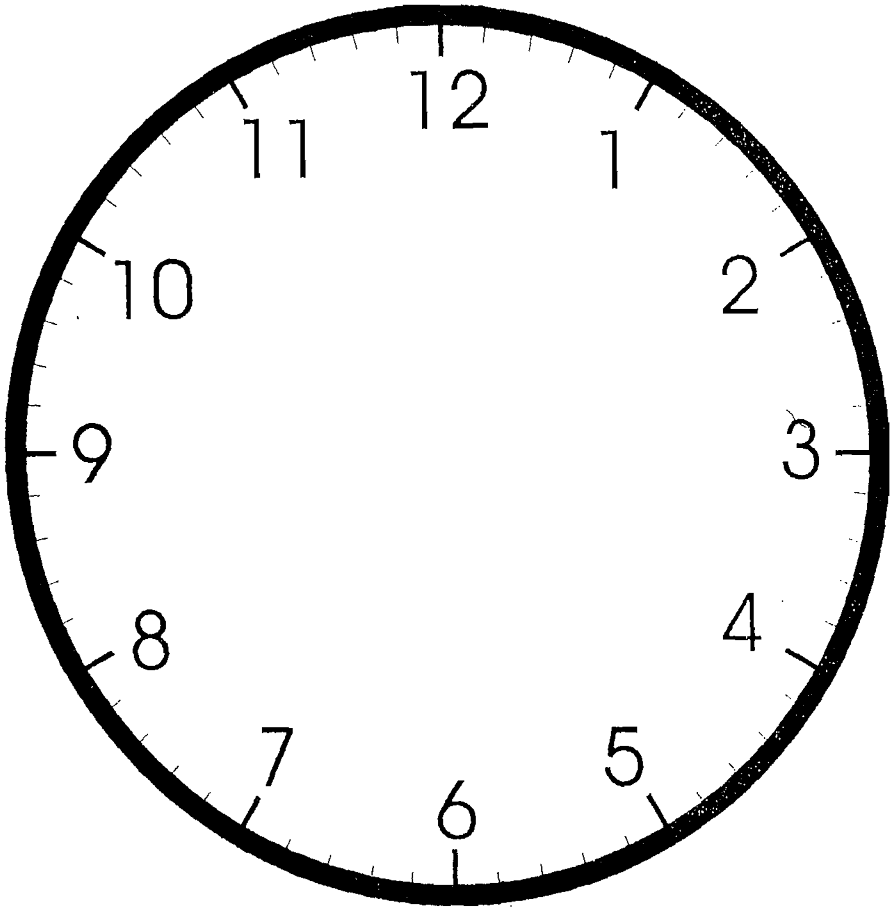
APPENDIX B

The following templates were used among participants. The first template was for the free-drawn condition; the second template (clock contour provided) was for the pre-drawn condition; the third template (mimeographed clockface) was for the examiner condition.

NAME:____ SEX: F M YEAR: 1 2 CONDITION: 1 2 3 4



NAME:______________________ SEX: F M YEAR: 1 2 CONDITION: 1 2 3 4



NAME:________________________________ SEX: F M YEAR: 1 2 CONDITION: 1 2 3 4