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Prevalence of positional nystagmus during static positional testing in normal healthy population using video-nystagmography

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A dissertation submitted in partial fulfilment of the requirements for the degree of MSc by instructional course

I, Irena Svandelkova, declare that the thesis is my own work, except where acknowledged, and that the research reported in this thesis was conducted in accordance with the principles for the ethical treatment of human subjects as approved for this research by the Ethics Committee at the Institute of Sound and Vibration Research, University of Southampton.

ABSTRACT

Positional nystagmus (PN) is a type of nystagmus that occurs as a result of the head or the head and body being moved from one position to another and then statically maintained in the critical position. Until recently, PN was always considered as an abnormal finding regardless of its character. However, with emergence of the highly sensitive technique of videonystagmography (VNG) it has become apparent that PN does occur frequently in healthy individuals. Since the present criteria for determining pathological PN have been based on electronystagmography (ENG), which provides less sensitive measure of vertical eye movements than VNG, there have been attempts to outline new criteria based on the VNG method. However, to date, no new explicit criteria have been agreed on by scientists. Further to this, a number of factors have been found to affect results of static position testing, including mental alerting, response repeatability, and the number of head and body positions tested, and these factors all need to be examined.

Apart from investigating prevalence of PN in healthy normal individuals, this experiment examined three variables: the effects of mental alerting, within session repeatability of PN, and the prevalence of PN across different head and body positions. Eighteen participants (13 female, 5 male) aged 22 to 76 years with no history of balance disorder were tested in four identical sets of static positional testing using VNG. Each test set included 11 head and body positions. Two of these test sets were conducted with mental alerting and two sets without mental alerting. Gathered data were analysed with respect to presence of PN, direction of PN, and peak slow phase velocity (SPV).

In total 66.7% of the participants developed persistent PN in at least one test position in at least one of the four test sets. Three main types of PN were found in this study: vertical, horizontal, and oblique. The most common type of PN across the entire study was vertical up-beating (VUB) PN (45.6%); however, the most common type of PN across individual participants was horizontal PN (75%). Oblique PN had the greatest mean peak SPV. Mental alerting had significant effect on prevalence of PN, but it did not increase the magnitude of the SPV. The prevalence of PN was only modestly repeatable within the paired mental alerting and non-mental alerting test sets, and the repeatability was greater for the test sets with mental alerting. There were no significant differences between the SPV magnitudes within the paired test sets, suggesting good within-session repeatability of the SPV magnitudes. The ‘supine with head straight’ (SHS) and ‘supine with head turned right’ (SHR) positions provoked the highest rates of PN; however, there was no one position that would not provoke PN in at least one participant and at least one test set.

Overall 22.2% of the participants did not fit the current criteria for ‘normality’ based on ENG, indicating the need for refinement of those criteria using VNG.

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LIST OF ABBREVIATIONS

A1	First test set with mental alerting
A2	Second test set without mental alerting
BLS	Body left side
BPPV	Benign paroxysmal positional vertigo
BRS	Body right side
BSA	British Society of Audiology
C	Caloric test position
CHL	Caloric test position with head turned 45° left
CHR	Caloric test position with head turned 45° right
CNS	Central Nervous System
CVS	Central vestibular system
CRPs	Corneo-retinal potentials
ENG	Electronystagmography
HCs	Hair cells
HHL	Head hanging left
HHR	Head hanging right
HHS	Head hanging straight
HL	Sitting with head turned left
HLB	Horizontal left-beating
HR	Sitting with head turned right
HRB	Horizontal right-beating
HU	Sitting head upright
LFD	Left forward Dix-Hallpike
NA1	First test set with no mental alerting

NA 2	Second test set with no mental alerting
NIN	Nicotine-induced nystagmus
OME	Otitis media with effusion
P	Prone
PAN	Positional alcohol nystagmus
PN	Positional nystagmus
ODLB	Oblique down and left beating
OULB	Oblique up and left beating
OURB	Oblique up an right beating
PTA	Pure tone audiometry
RFD	Right forward Dix-Hallpike
SCCs	Semi-circular canals
SD	Standard deviation
SHL	Supine head turned left
SHR	Supine head turned right
SHS	Supine head straight
SN	Spontaneous nystagmus
SPV	Slow phase velocity
TM	Tympanic membrane
VCR	Vestibulo-collic reflex
VDB	Vertical down-beating
VNG	Videonystagmography
VOR	Vestibulo-ocular reflex
VSR	Vestibulo-spinal reflex
VUB	Vertical up-beating

CHAPTER 1 – INTRODUCTION

1.0 Dizziness and static positional testing

In the United Kingdom, dizziness is one of the most common reasons for seeking medical help. According to Yardley et al. (1998), ten percent of adults experience problems with dizziness at some stage of their lives. This problem is especially endemic in older people (Johkura et al., 2008). The reasons for the dizziness vary, ranging from cardiovascular, psychiatric, and multifactorial problems to peripheral or central vestibular disorders. In order to obtain a differential diagnosis and identify the site and cause of a potential vestibular disorder, a careful medical history must be taken. This is to understand the exact nature of the patient's complaint and determine which vestibular tests need to be put in place. Two key questions need to be addressed during a vestibular assessment. Firstly, it needs to be established whether the patient's problem is of a true vestibular origin. Secondly, provided that a vestibular disturbance is confirmed, it needs to be differentiated whether the disturbance is peripheral vestibular (the inner ear or the vestibular nerve) or central vestibular (the brainstem or the cerebellum) (Kerr, 2005).

An important element of the battery of vestibular tests is static positional testing, which allows any manifestation of positional nystagmus (PN) when a patient's head is placed in different positions with regard to gravity (Herdman, 1994). Traditionally, two methods of measurement of PN are available. The first traditional method, electro-nystagmography (ENG), measures corneo-retinal potentials (CRPs) created by the positively polarised cornea and the negatively polarised retina as the eyes move (Jacobson et al., 2008). The second more recent method, video-nystagmography (VNG), employs goggles with two small embedded infrared cameras that video-track movements of the pupils. Until recently, PN was always considered as an abnormal finding regardless of its character. However, with emergence of the highly sensitive technique of VNG it has become apparent that PN can and does occur in healthy individuals. The mechanism behind PN in both the individuals with dizziness and healthy normal participants remains unclear (Coats, 1993). Since the present criteria for determining pathological PN have been based on the ENG method, which provides less sensitive measure of vertical eye movements than the VNG method due to high level of artefacts in the vertical recording channel, there have been attempts to outline new criteria based on VNG (Barin & Roth, unpublished, cited in Barin, 2006; Copperwheat, 2005). However, to date, no new explicit criteria have been agreed on by the scientists. A number of factors have been found to affect results of static position testing, including mental alerting, response repeatability, and number of head and body positions tested, which all need to be considered when conducting the test and interpreting the test results.

1.1 The anatomy and physiology of the balance system

The main role of the balance system is to provide awareness of motion, spatial orientation, and clear stable vision during head movement. This is done through a complex relationship between three peripheral sensory systems: the visual, vestibular, and somatosensory (proprioception). The inputs from these systems are conveyed to the brain where they are processed and reflected in the form of vestibular reflexes (Schubert & Shepard, 2008).

1.1.1 The peripheral vestibular system

The inner ear, which is enclosed within the petrous portion of each temporal bone, contains the membranous vestibular labyrinth. Each labyrinth consists of five neural structures enabling detection of head movements. The three semi-circular canals (SCCs), known as horizontal, anterior, and posterior SCCs, represent the dynamic balance system, and the saccule and the utricle, known as the otolith organs, represent the static balance system (Schubert & Shepard, 2008) (Figure 1.0).

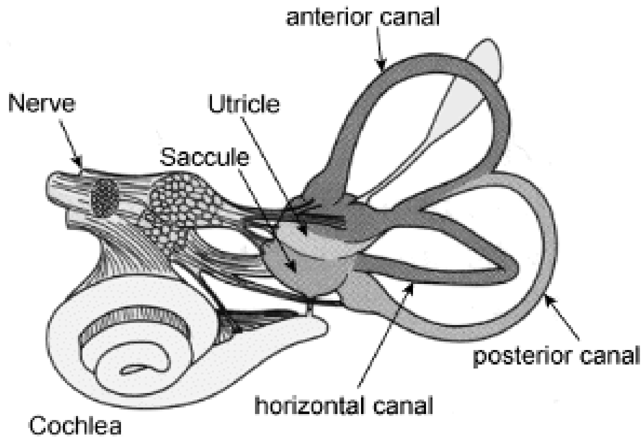

Figure 1.0*: Anatomy of the inner ear (Wikipedia [Online], 2009). Reprinted with permission.*

Within the inner ear, the SCCs are positioned approximately perpendicularly (at right angles) to each other. They are functionally paired between the two vestibular labyrinths, creating three corresponding functional planes. The horizontal canals of each labyrinth form one such a plane, whereas the anterior SCC and contralateral posterior SCC form another plane (Schubert & Shepard, 2008). The primary function of the SCCs is to translate angular head acceleration into neural firing, which is then processed by the higher centres (Honrubia & Hoffman, 1997).

The SCCs are filled with fluid called endolymph, which has a high content of potassium and a low content of sodium. Its density is slightly greater than the density of water (Schubert & Shepard, 2008). The SCCs have one enlarged end, the ampulla. Within the ampulla there is a gelatinous structure known as the cupula. The cupula spreads across the whole lumen of the SCC, creating what has been described as a 'water-tight seal' (Honrubia & Hoffman, 1997) (Figure 1.1). The cupula and endolymph have an equal density. For this reason, the cupula is not sensitive to static positional changes. Directly underneath the cupula lies the crista, which holds the ciliated sensory hairs cells (HCs) together with the vestibular afferents. The HCs of the crista, which are embedded in the cupula, are equipped with a number of shorter stereocilia and a single tall kinocilium on their tops.

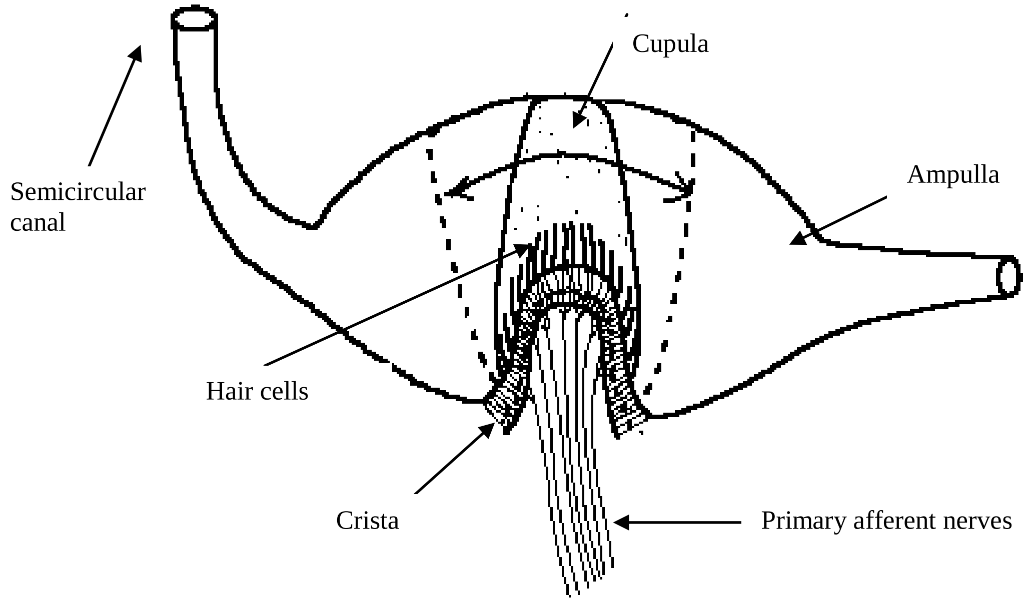

Figure 1.1: *A simplified illustration of the inner structure of a SCC. The scattered line represents the range of the cupula displacement during angular acceleration (Adapted from http://www.unmc.edu/physiology/Mann/pix_9/cupola.gif).*

The HCs of the SCCs also contain vesicles that hold a neurotransmitter. When the head moves, the HCs respond to cupular deformation caused by the motion of the endolymph. The fine movements of the HCs result in the corresponding opening or closing of the transduction channels, the release of the neurotransmitter, changes in electrical polarity of the HCs membrane, and consequent increase or decrease in the rate of the neural firing of the vestibular afferents. When the stereocilia bend towards the kinocilia, this causes the membranes of the HCs to depolarise. The depolarisation produces an increased rate of firing in the vestibular afferent fibres. When the stereocilia deflect away from the kinocilia, this leads to hyperpolarisation and a decreased rate of neural firing (Figure 1.2). Due to a specific orientation of the HCs within the three SCCs, movement of the endolymph towards the ampulla in the horizontal SCC causes excitation, while movement of the endolymph towards the ampulla in the anterior and posterior canals causes inhibition (Schubert & Shepard, 2008).

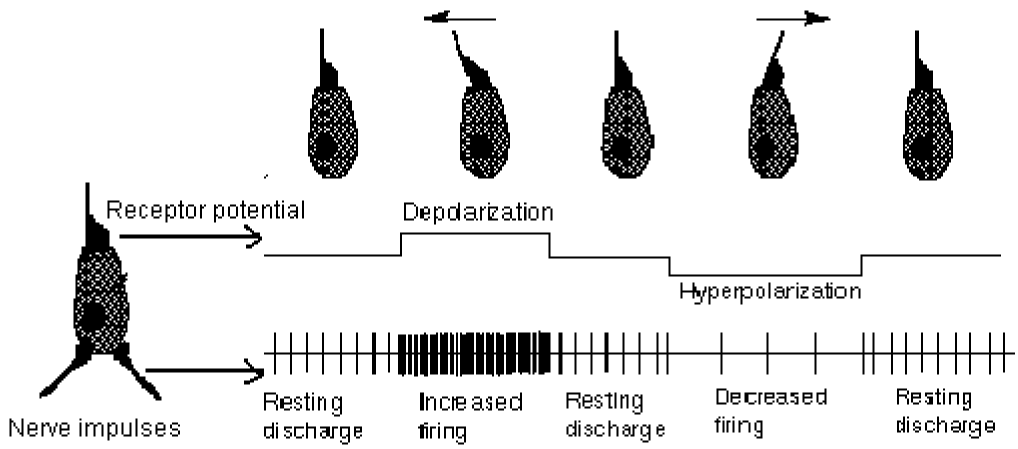

Figure 1.2: N*eural firing of the HCs of the SCCs (Adapted from http://www.neurophys.wisc.edu/h&b/textbook/fig5-5.gif.).*

The saccule and the utricle are known as the otolith organs. Similar to the SCCs, the otolith organs contain sensory hair cells. The HCs are embedded in surfaces of the otolith organs, the maculae, and project into a gelatinous mass containing calcium carbonate crystals that arches above them (Figure 1.3). The crystals, otoconia, have mass and therefore a greater specific mass than that of the endolymph. As a result, the maculae respond to linear acceleration (motions such as jumping, tilting the head, starting, or stopping) and gravity. Due to partitions of the otolith organs by central regions called the striola, the utricle and the saccule have different orientation of their HCs relative to the kinocilia. The utricle has its kinocilia orientated towards the striola, while the saccule has its kinocilia orientated away from the striola. Consequently, the utricle responds to horizontal linear acceleration and static head tilt, and the saccule responds to vertical linear acceleration (Schubert & Shepard, 2008).

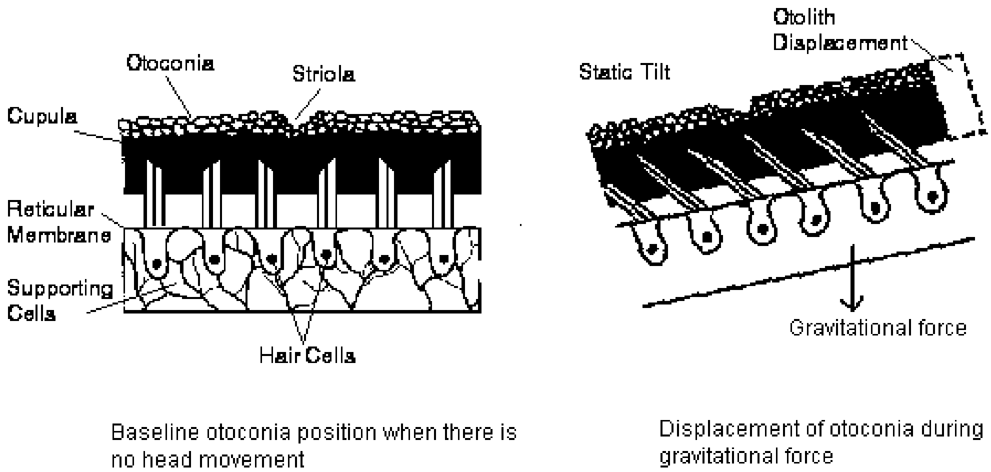

***Figure 1.3**: Structure and functioning of the otolith organs (Adapted from http://commons.wikimedia.org/wiki/File:Balance_Disorder_Illustration_B.png).*

1.1.2 Vestibular reflexes

There are a number of vestibular reflexes that facilitate awareness of head and body position in the space and contribute to stable vision and body posture. The vestibulo-ocular reflex (VOR), upholds images on the fovea of the eye retina during active head movement. The vestibulo-spinal reflex (VSR) maintains steady body position and its centre of gravity by creating a functional arch between the vestibular system and muscles. Since there is a much longer distance between the inner ears and the rest of the body than the distance between the inner ears and eyes, the VSR is slower than the VOR, yet fast enough to prevent falls during unexpected body movements. Finally, the vestibulo-collic reflex (VCR) maintains steady head and neck position during body movements (Schubert & Shepard, 2008).

The fovea of the retina is a small part of the retina that provides very high resolution due to having a large amount of retinal receptors. Since the rest of the retina lacks this ability, it is crucial for the eye to be able to achieve accurate position and maintain the viewed images. Therefore, as the head rotates, the VOR triggers compensatory eye movement in an opposite direction, which prevents images ‘slipping’ from the retina (Roberts & Gans, 2008). The eye movement is achieved by the pull of six extraocular muscles that are arranged into pairs and linked to the three SCCs. The medial and lateral recti allow horizontal eye movement. The superior and inferior recti allow vertical eye movement. Finally, the superior and inferior oblique muscles permit vertical as well as torsional eye movement (Hain & Rudisill, 2008). Figure 1.4 represents a schematic depiction of horizontal eye movement.

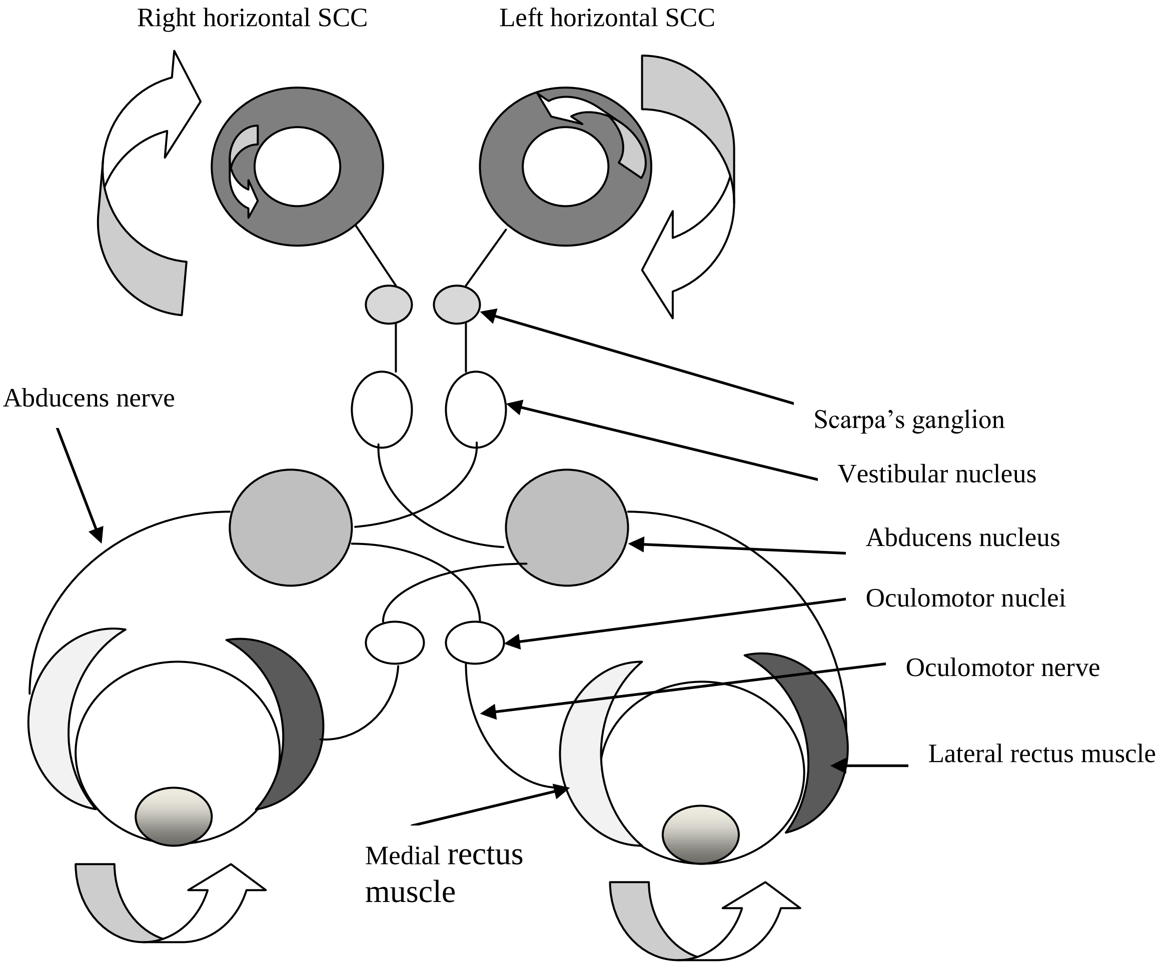

Figure 1.4: *A simple three-neuron arc of the vestibulo-ocular reflex.*

The latency of the VOR has been shown to be very short, approximately 5 to 7 milliseconds (Huterer & Cullen, 2002). This permits highly stable vision even during rapid head-movements. The VOR is elicited by the difference in neural firing in afferent vestibular nerves of associated SCCs during head or head and body motion, with respect to the plane of the movement (McCaslin et al., 2008). Movement of the head results in an increase of neural firing in the associated SCC the head is moving towards and a decrease of neural firing in the SCC of the contralateral ear.

The average baseline tonic firing rate of afferent vestibular nerves that extend from the SCCs to the vestibular nuclei is approximately 70 to 90 spikes per second (Goldberg & Fernandez, 1971, as cited in McCaslin et al., 2008). During angular head movement ipsilateral vestibular afferents start firing at rate as high as 400 spikes per second. This is accompanied by hyperpolarisation (inhibition) of the afferents of the contralateral SCC. The central vestibular system (CVS) transfers this neural pattern to the oculomotor nuclei, which maintains tonus of the oculomotor muscles (McCaslin et al., 2008). When the head moves in one direction, eyes shift in an exactly opposite direction. The velocity of these movements is equal and known as the gain of the VOR. However, while the output of the VOR tends to be linear at low head acceleration and velocity, it becomes nonlinear during higher acceleration and velocity (Lasker et al., 2000). This may be due to unique afferent physiology, which consists of two groups of vestibular afferents, regular and irregular, with each group responding to different ranges of frequency and acceleration of head movements (Schubert & Shepard, 2008).

1.1.3 Central processing of the vestibular input

The four vestibular nuclei that are located in the brainstem receive information from the vestibular labyrinth. The primary vestibular input is conveyed to them ipsilaterally via one of the two branches of the vestibular nerve. The horizontal SCC, the anterior SCC, and the utricle are served by the superior vestibular nerve. The posterior SCC and the saccule are served by the inferior vestibular nerve. Evidence however suggests that the posterior SCC may be innervated by both the superior and inferior vestibular nerves (Brodal & Brodal, 1985).

Information from the vestibular nuclei is then passed onto the extraocular motor nuclei, the cerebellum, and the brainstem via secondary vestibular afferents. While the brainstem is the main centre for controlling vestibular reflexes, extensive links have been found between the vestibular nuclei and the reticular formation, cerebellum, and thalamus (Schubert & Shepard, 2008). Vestibular fibres continue up to the junction of the parietal and insular lobes, which has been identified as the location for the vestibular cortex (Brandt et al., 2002).

1.2 Nystagmus

Nystagmus is described as an involuntary eye movement. This movement can be horizontal, vertical, oblique, or torsional (Barin, 2006). When recorded, nystagmus resembles a sawtooth waveform (Carl, 1997). A typical nystagmus trace consists of a slow and fast movement of the eyes, known as a slow and fast phase (Figure 1.5). In nystagmus of a vestibular origin the slow phase is generated by the vestibular system, whereas the fast phase represents the corrective response of the central nervous system. By convention, the fast phase, which can be observable to a naked eye, is used to describe the direction of the nystagmus. However, it is the slow phase velocity (SPV) that is measured (Carl, 1997). The SPV represents intensity of the nystagmus and it is calculated by dividing the distance that the eye travelled during the slow phase by the amount of time taken. The SPV is then defined in degrees per second (°/s) (Barin, 2004).

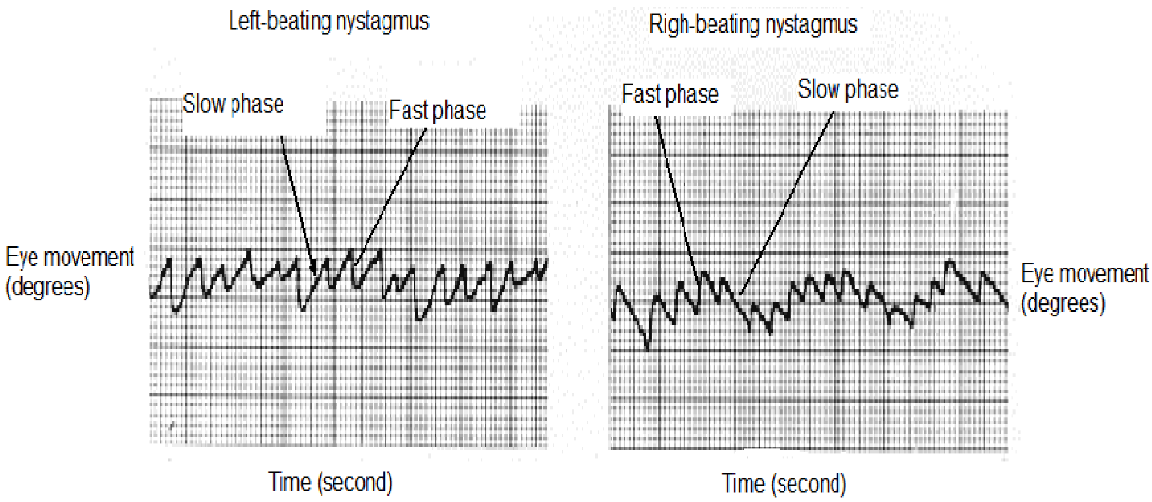

Figure 1.5: *Left-beating and right-beating horizontal nystagmus (in degrees per second) with their fast and slow phases.*

While nystagmus occurs frequently physiologically, for example when following a fast moving visual pattern, pathological nystagmus may be seen when there is a problem in either the peripheral or the central vestibular system. Nystagmus due to peripheral vestibular disorder is generally well suppressed with visual fixation, whereas nystagmus due to central disorder is often present even with the fixation (Hood & Korres, 1979). In order for nystagmus to become visible, and to be able to differentiate between peripheral and central disorders, nystagmus is usually measured with visual fixation removed (McCaslin et al., 2008).

In general, there are two main categories of nystagmus: spontaneous and evoked nystagmus. Spontaneous nystagmus (SN) is a type of nystagmus that occurs without any provocation, and can be of congenital, acquired, central, or peripheral vestibular origin. In contrast, evoked nystagmus is a type of nystagmus that requires stimulation to occur, for instance a movement of the head or the body. A typical example of evoked nystagmus is positioning nystagmus, which occurs in a condition called benign paroxysmal positional vertigo (BPPV). In this condition otoconia break free from the macula of the otolith organs and float in one of the vertical SCCs (usually posterior SCC), causing hydrodynamic drag. This results in outbursts of short-lived vertigo during fast head movements in a certain direction (Roberts & Gans, 2008). One other variety of evoked nystagmus is positional nystagmus (PN), which is a focus of this manuscript.

1.2.1 Positional nystagmus

There has been some confusion in the current literature when describing PN. Some authors made no distinction between PN and SN when investigating their presence in healthy individuals (Coats, 1993; Bisdorff et al., 2000). Similarly, some authors referred to the observed nystagmus as PN, even though the nystagmus was in fact positioning and not positional (Jokhura et al., 2008; Geisler et al., 2000; Levo et al., 2004). Strictly speaking, PN is a type of nystagmus that occurs as a result of the head or the head and body being moved from one position to another and then statically maintained in the critical position. Hence, it is not the movement but the new stationary position that triggers PN (Barin, 2006). The nystagmus elicited by the new static position is persistent and positional in its origin, and lasts as long as the head stays in the new position. In contrast, positioning nystagmus is provoked by the act of moving head and body quickly in a certain direction and usually fades away over a short period of time. Since the mechanism for eliciting these two types of nystagmus is different, they need to be clearly differentiated. However, PN can be sometimes mistaken for nystagmus due to cupulolithiasis of the horizontal SCC, which also presents with persistent nystagmus. In this condition otoconia break free from the otolith organs and become attached to the cupula, making it gravity-sensitive. This is typically accompanied by paroxysmal vertigo and direction-changing nystagmus that becomes stronger when the patient's head is turned to the unaffected side. These findings help to distinguish nystagmus due to cupulolithiasis of the horizontal SCC from PN (Boleas-Aguirre et al., 2009).

A number of PN classifications have been proposed over past years. For example, Aschan et al. (1956) differentiated three types of PN. According to Aschan et al. (1956), type I PN is persistent and direction-changing. For example, if a patient's head is turned to the right, right-beating nystagmus can occur. When it is moved to the left, the PN reverses and starts beating to the left. Type II PN is direction-fixed, which means that the PN always beats in the same direction in spite of the head position. Type III PN is of a transient character, which means that the PN disappears while the head/ or the body is placed in the critical position. A typical example of PN under this classification system would be paroxysmal positioning nystagmus as in canalithiasis of the anterior or posterior SCC. However, since the nystagmus due to canalithiasis is of a positioning origin, such a classification is problematic.

At the present, PN is commonly described in terms of its character (horizontal, vertical, oblique, or torsional), direction (direction-fixed or direction-changing), duration (persistent or intermittent), and fixation (present or absent with fixation) (Barin, 2006). Direction-fixed PN is eye movement that always beats towards the same side regardless the head position. One other example of direction-fixed nystagmus is SN, which often occurs in cases of a recent unilateral peripheral vestibular failure, and from which PN needs to be differentiated. Spontaneous nystagmus is typically horizontal, sometimes with an additional torsional component, and its intensity is not affected by head movements into different positions (McCaslin et al., 2008). In contrast, direction-changing PN can reverse its direction depending on the head position in space. There are two subdivisions of horizontal direction-changing PN, geotropic and ageotropic PN. While geotropic PN always beats towards the ground when a patient's head or head and body are turned to one side, ageotropic PN always beats away from the ground (Bronstein & Lempert, 2007). One other example of direction-changing PN is periodic alternating nystagmus, which is the nystagmus changing its direction in a single head position approximately every two minutes, and which is a rare finding caused by a central lesion (Kennard et al., 1981).

In terms of duration, PN nystagmus can be described as persistent or intermittent (sporadic). However, there is no clear definition in the literature of what this constitutes. Barber and Wright (1973) classified persistent PN as nystagmus lasting longer than 30 seconds and intermittent PN as nystagmus lasting fewer than 30 seconds. Other authors considered PN to be persistent if the PN occurred in at least 80% of the time for each tested condition (McAuley et al., 1996). Some authors provided no criteria at all (Schneider, 2002). Barin (2006) has argued that intermittent PN is often linked with technical issues, such as low level of mental alertness or direction of the gaze, and therefore this parameter should not be used when determining presence of pathological nystagmus.

1.2.2 Measurement of nystagmus

Since the peripheral vestibular system lies deep within the temporal bone and there is no direct access to it, its function can be assessed only by indirect measurement of eye movement. Currently, two types of systems are commonly used in clinics for measurement and recording of eye movement. These are electronystagmography (ENG) and videonystagmography (VNG).

The ENG method is based on electro-oculography, which measures corneoretinal potentials (CRPs) created by the positively polarised cornea and the negatively polarised retina as the eyes move (Jacobson et al., 2008). During the ENG recording, a number of conventional surface electrodes are placed around a patient’s eyes. These electrodes measure the standing potential. However, there are a number of disadvantages to this method, including calibration drift, electrical noise, and inability to record vertical eye movements accurately. For this reason the ENG method is slowly being replaced by the VNG method.

The VNG method is based on a completely different technology compared to ENG. This method employs goggles with two small embedded cameras that video-track movements of the pupils. Currently, there are two main VNG systems available. The first one, bright-pupil system, uses an infrared illumination source at the level of the camera. As the light reflects from the retina, the pupil appears bright in relation to the surrounding iris. As a result of the contrast in brightness between the pupil and the iris, the cameras can identify the pupil highly accurately. The second VNG system, the dark-pupil tracking system, utilises off-axis illumination to create a contrast between the pupil and the iris. This means that the light is not parallel to the axis of the optical system. Using this method, the pupil becomes darker relative to the more reflective iris. In both methods, the boundary of the pupil and the iris is located through computer analysis of the video signal using a circle detection algorithm known as Hough transform. The calculation of eye position is done by obtaining at least two reference points. One of them can be the centre of the pupil and the other a place of reflected light pattern on the cornea (Jacobson et al., 2008).

The VNG goggles are generally well-tolerated and the system quicker to use compared to the ENG system since no skin preparation is necessary. The goggles provide a ‘light-tight’ seal, ensuring the removal of fixation. Furthermore, since CRP play no role in this method; frequent recalibrations are unnecessary since change in illumination does not affect the precision of measurements as it does with ENG. The system can measure and video-record vertical eye movements and visualise and video-record torsional eye movements, making the VNG a perfect tool for detecting BPPV (Jacobson et al., 2008). However, this method also has some disadvantages. The high cost of the VNG system means that it may not be accessible to all vestibular clinics and there may be some difficulties of recording eye movements where the patient has a droopy eye lid. Furthermore, ‘crosstalk’ may occur during recordings. The crosstalk represents false activities in one channel due to eye movements in the other channel. This phenomenon, which arises from misalignment of cameras within the VNG goggles, may affect interpretation of the test results (Barin, 2008). Crosstalk can be identified by asking a patient to move their eye in the horizontal plane and observe for any response in the vertical channel.

1.3 Performing the static position test

Similar to the discrepancy when referring to PN, there has been some confusion in the literature when authors describe different types of position tests. Some authors refer to the static and dynamic position tests as positional and positioning testing, respectively (Jokhura et al., 2008; Geisler et al., 2000). This can be misleading, especially since these tests provoke nystagmus with different characters. In order to prevent further confusion, it has been recommended that these tests are referred to as static and dynamic position tests (Barin, 2006). A typical example of a dynamic position test is the Dix-Hallpike manoeuvre, which is a test for presence of BPPV of the anterior or posterior SCCs. This manoeuvre entails positioning a patient on an examination couch in such a way that their legs are rested on the couch, their head turned 45° towards one side, and their upper body and head are brought down rapidly while providing support for the patent's neck and the head. The head is kept hanging 15-20° below horizontal, beyond the end of the couch, for at least 30 seconds whilst observing for positioning nystagmus. After this the patient is sat up and the same process repeated with the head turned towards the other side (British Society of Audiology, 1992a). In contrast, the static position test requires slowly moving the patient's head or head and body into a number of different positions, which are each maintained for at least 30 seconds. This is typically the amount of time required for the PN to manifest (Roberts & Gans, 2008).

Before commencing static position testing the presence of SN must be ruled out by performing the spontaneous nystagmus test, which examines a patient's ability to maintain stable gaze when looking ahead, to the left, and to the right while the head is kept still. This is in order to prevent misdiagnosis of SN for PN. It has also been recommended that the static position test be performed in a specific order relative to other vestibular tests. For example, positioning testing, such as the Dix-Hallpike manoeuvre, should be performed prior to positional testing. This is because the BPPV response fatigues with repeated changes in position (Roberts & Gans, 2008). Furthermore, the caloric test should be performed after the positional test. The caloric test is a part of the vestibular test battery during which the external ear canal is irrigated by a bithermal medium (e.g. warm and cool water) that differs significantly in temperature from the body's temperature (British Society of Audiology, 2010). The difference in the temperature then stimulates the horizontal SCC. The recommendation to carry out the static positional test before the caloric test is based on evidence suggesting that the caloric irrigations temporarily increase incidence of PN (Barber & Wright, 1973; Wu & Young, 2000).

1.3.1 Contraindications

Since positional static testing involves placing a patient's body and head in various positions, a clinician needs to judge whether there is any reason why the testing could be deemed unsafe. At the present there is no recommended test procedure for the static position test and thus no clearly specified contraindications of the test. For this reason the recommended procedure for the Dix Hallpike test, which also involves positioning of the head and body, could serve as a substitute. According to British Society of Audiology (1992a), the absolute contraindications for performing the Dix Hallpike test are a spinal fracture, cervical disc prolapse, vertebro-basilar insufficiency, and recent neck trauma preventing torsional head movement. Relative contraindications involve sick carotid sinus, severe neck or back pain including rheumatoid arthritis, severe breathing problems, recent neck surgery, cardiac bypass surgery performed within the last three months, and a recent stroke. Even though it is the responsibility of the referring physician to make sure that a patient can undergo positional testing, the attending audiologist must not omit an enquiry about all potential contraindications.

1.3.2 Test positions

As discussed earlier, there is no recommended procedure concerning the static position test. As a result, various positions, and combinations of various positions, have been used by researchers in static positional testing. In fact, as many as 17 different positions and six different combinations of positions have been identified in the reviewed studies using VNG technology (Table 1). Since none of these studies used an identical set of positions to another study, a direct comparison of these studies is difficult. Figure 1.6 depicts 14 most commonly used positions as described in reviewed normative studies using VNG technology.

Table 1.0: *Positions that were used in static position testing in studies using VNG. Two crosses represent a position with the highest incidence of PN. Codes: 1=sitting head upright (HU), 2= sitting head turned right (HR), 3= sitting head turned left (HL), 4=supine head straight (SHS), 5=supine head turned right (SHR), 6=supine head turned left (SHL), 7=head hanging straight (HHS), 8=head hanging right (HHR), 9=head hanging left (HHL), 10=body right side (BRS), 11=body left side (BLS), 12=caloric test position (C) (head elevation 30°), 13= caloric test position head turned 45° right (CHR), 14= caloric test position head turned 45° left (CHL), 15=prone (P), 16= right forward Dix-Hallpike (RFD) (from position 8 to bending the head forward towards the right knee with head rotation 45°), 17= left forward Dix-Hallpike (LFD*) (*from position 9 to bending the head forward towards the left knee with head rotation 45°)*

	Positions used (+) in normative studies using VNG						
Position number and Code	Unpublished study by Barin and Roth (cited in Barin,2006)	Copperwheat (2005)	Levo et al. (2004)	Sunami et al. (2004)	Schneider (2002)	Bisdorff et al. (2000)	Geisler et al. (2000)
1= HU	+				+	+	+
2= HR		+					
3= HL		+					
4= SHS		+	+		+	**++**	+
5= SHR		+	**++**		+	+	+
6= SHL		+	**++**		+	+	+
7= HHS		+		+			
8= HHR		+		+	+		+
9= HHL		**++**		+	**++**		+
10= BRS	+	+		**++**	+		
11= BLS	+	**++**		**++**	+		
12= C	+	+		+	+		+
13= CHR	+			+			+
14= CHL	+			+			+
15= P						+	
16= RFD							**++**
17= LFD							+

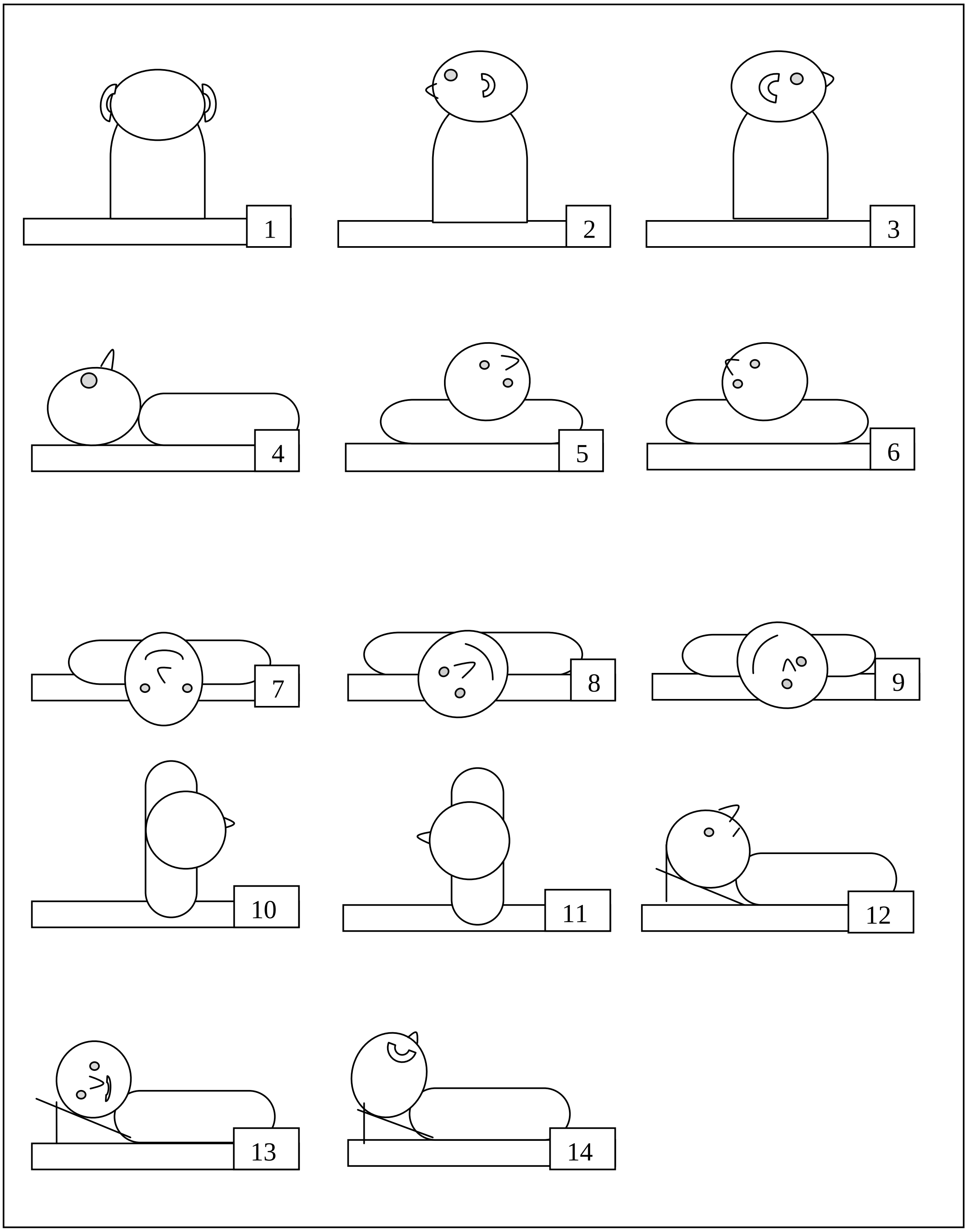

Figure 1.6: *The 14 most commonly used positions in static positional test. 1=sitting head upright (HU), 2= sitting head turned right (HR), 3= sitting head turned left (HL), 4=supine head straight (SHS), 5=supine head turned right (SHR), 6=supine head turned left (SHL), 7=head hanging straight (HHS), 8=head hanging right (HHR), 9=head hanging left (HHL), 10=body right side (BRS), 11=body left side (BLS), 12=caloric test position (C) (head elevation 30°), 13= caloric test position head turned 45° right (CHR), 14= caloric test position head turned 45° left (CHL).*

Barin (2006) recommended the use of six standard test positions. These include: sitting with head upright (HU), caloric test position (i.e. supine with head elevated by 30°) (C), caloric test position with head turned 45° to the right (CHR), caloric test position with head turned 45° to the left (CHL), body right side (BRS), and body left side (BLS) positions (Figure 1.6). Barin (2006) argues that this subset of positions is sufficient in order to provide useful clinical information. This is in line with recommendation of Roberts and Gans (2008) who also advocate this standard set.

In contrast to this, Copperwheat (2005) used as many as 11 positions, however with no rationale given for the choice. Copperwheat (2005) included these positions: sitting head turned right (HR), sitting head turned left (HL), supine head straight (SHS), supine head turned right (SHR), supine head turned left (SHL), head hanging straight (HHS), head hanging right (HHR), head hanging left (HHL), body right side (BRS), body left side (BLS) and caloric test position (C) (Figure 1.6). A similar proposal came from Shepard and Telian (1996) who argued that the head hanging positions can help to investigate the effects of various head positions within the gravitational field. While Barin (2006) argues that there is no necessity to include the head hanging positions in static position testing, as they are a part of the dynamic position test, Brandt (1997) proposes the exact opposite by recommending to carry out the position static test as part of the dynamic position test with the use of the same positions (HU, HR, HHR, HL, HHL). According to Brandt (1997), static positional testing can be easily integrated into the dynamic position test by keeping the head or the head and body in a critical position for long enough (at least 20 seconds), hence any positioning nystagmus can subside and true PN appear.

According to Barin (2006), the HU position provides some verification of the reliability of overall VNG testing, since this position is also a part of the test for SN. Following this logic, the C position can provide similar benefit, as it is typically used as a neutral position to which a patient is returned to in between other movements. The BRS and BLS positions have been argued not to provide any additional clinical information to the supine with head turned 45° to right (SHR) and supine with head turned 45° to left (SHL) positions, unless there is a significant PN in the SHR and SHL positions (Barin, 2006). Instead, these positions could be used as a substitution for the head turning manoeuvres when there is a problem with the neck or back in a patient (Barin, 2006). However, a study by Aoki et al. (2008) suggested that the BRS and BLS positions may provide more valuable clinical information than the SHR and SHL positions. Aoki et al. (2008) tested the efficiency of three different static positional manoeuvres on 86 patients with dizziness. All manoeuvres were initiated from a supine-lying position. The first manoeuvre involved turning a patient's body to one side, while the head remained in its original position. The second manoeuvre involved turning the head only, while the body remained still. Finally, the third manoeuvre involved turning both the head and body simultaneously to one side. Thirty four out 86 patients showed PN in at least one position. Out of these, 9% had PN provoked by the 'body only' position, 16% had PN provoked by the 'head only' manoeuvre, and 33% had PN provoked by the 'head and body' manoeuvre. The differences in the provocation rates were statistically significant for the 'head and body' manoeuvre compared to the two other manoeuvre. Aoki et al. (2008) suggested that the 'head and body' manoeuvre is more effective in stimulating the otolith and therefore should be used instead of simple 'head-only' manoeuvre.

As discussed above, there is a general disagreement in the literature on the number and types of positions recommended by different authors. Furthermore, there is no evidence suggesting that one particular position is more efficient in provoking PN than the other. Similarly, there is no evidence suggesting that one particular position lacks the ability to provoke PN. McAuley et al. (1996), who recorded PN using ENG, and employed an identical set of positions as recommended by Barin (2006), found that no one position had a predominant ability to elicit PN over other positions. In contrast, Bisdorff et al. (2000) reported the highest PN incidence in the SHS position. Schneider (2002) and Copperwheat (2005) on the other hand found the highest PN rates in the HHL position. Finally, Sunami et al. (2004) found the highest rates in the BRS and BLS positions.

1.3.3 Speed of movement

It has been suggested that the speed at which a patient moves from one position to another should be slow and of a natural pace, with the clinician providing only gentle assistance (Barber, 1984). This slow movement is used in order to avoid occurrence of positioning nystagmus, which can be provoked by fast movements, such as during the Dix Hallpike manoeuvre. Barber (1984) recommended each movement should take at least 3 seconds. Similarly, Coats (1993) used 2 seconds to move a patient from one position to another. However, neither of these authors advised how the predetermined speed of movement was achieved. In contrast, Copperwehat (2005), who also used 3 seconds for each movement, employed a ticking metronome to encourage tested individuals to move at an even pace.

1.3.4 Visual fixation

The static position test is usually tested with vision denied. This is in order to prevent inhibitory actions of the vestibular nuclei that are capable of suppressing of vestibular generated nystagmus in the presence of vision (McCaslin et al., 2008). When an ENG system is used for recording eye movement, visual fixation can be removed by having patients open their eyes in the dark, keep their eyes closed in dim light, or open their eyes under the Frenzel lenses. When a VNG system is used, patients have their eyes open under the VNG goggles. Scientific literature suggests that use of VNG goggles is largely superior to any other method, since VNG goggles can provide not only total darkness, and thus effectively remove visual fixation, but can also be used to record eye movement, which can be examined at a later time (McCaslin et al., 2008).

1.3.5 Duration of recording

It is usually sufficient to record eye movements for 30 seconds in each test position. Brandt (1997) recommends observations last at least 20 seconds, which allows positioning nystagmus to be clearly differentiated from true PN. For the same reason Barin (2006) proposes to commence recording before the head is moved to a new plane. If transient positioning nystagmus occurs, recording should be continued until the nystagmus dissipates. Following this, a clinician needs to observe for any true PN arising as a result of the new static head position. There are certain clinical exceptions when recording needs to be continued for longer than 30 seconds. For example, in a case of periodic alternating nystagmus, the nystagmus changes its direction in a single head position approximately every two minutes (Baloh & Honrubia, 1990, as cited in Barin, 2006). This rare abnormality can be usually observed by contradictory findings during other vestibular tests, therefore preventive two-minute long recording in each head position is not necessary in individuals were there is no base for suspecting periodic alternating nystagmus.

1.3.6 Mental alerting

Mental alerting is a way of increasing mental arousal in a tested individual, which prevents central inhibition of nystagmus. It can come in a form of a simple mental task, such as counting or naming countries in an alphabetical order (McGovern & Fitzgerald, 2008). Mental alerting is routinely used during caloric testing (British Society of Audiology, 2010) and it has been recommended to be used also during the SN test (Takahashi et al., 1996). According to Barin (2006), mental alerting should be always used in those tests where testing is performed without fixation. However, there is still limited evidence supporting the application of mental alerting during static position test, and therefore some departments do not routinely incorporate it in their local protocols.

A study by Humphriss et al. (2005) investigated effects of mental alerting on magnitude of SN in 10 out of 80 studied patients. The study reported no significant differences in magnitude of the SN between the conditions with and without mental alerting, suggesting no effects of mental alerting on the magnitude of SN. However, this study was significantly underpowered due to the small cohort of tested patients. Furthermore, all tested individuals had already had significant SN, which may have affected the results.

In contrast, McGovern and Fitzgerald (2008) found that mental alerting had a significant effect on the presence and magnitude of SN and PN. The researchers investigated effects of mental alerting on a more robust sample of 30 dizzy patients during SN and static position tests using ENG. All recruited patients were known to have significant SN or PN with SPV larger than 6°/s in at least one test positions prior to the experiment. The static position testing was performed only in two positions, BRS and BLS, with counting used as a mental alerting task. Results of the static positional testing showed that mental alerting resulted in significantly greater SPVs (by ≥3 °/s) in seven out of 20 patients with PN (Figure 1.7). Out of these, four had no PN without alerting at all and three had PN with SPV less than 6°/s. This suggests that mental alerting can increase magnitude of the PN by a half in some individuals. Since some departments report PN only when the SPV is greater than 6°/s, this finding has an important clinical implication.

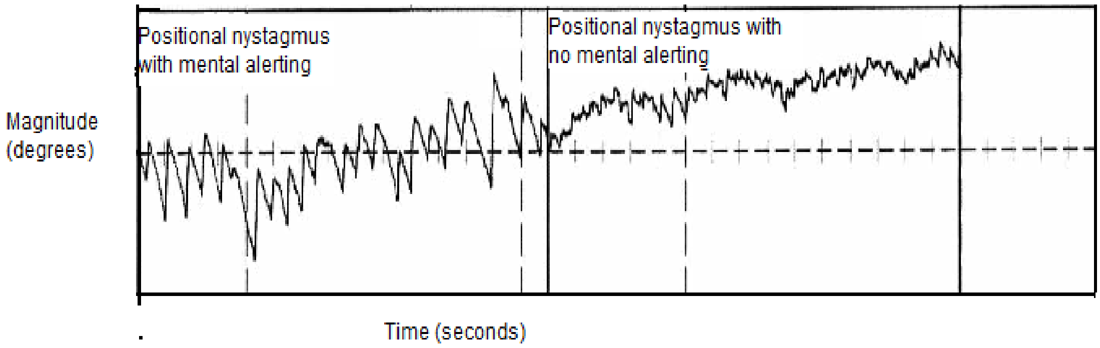

Figure 1.7*: Effects of mental alerting on one of the 20 patients with PN in body right position (Adapted from McGovern & Fitzgerald, 2008).*

1.3.7 Response repeatability

When PN is detected in a certain head and body position in a patient, a clinician may want to verify the finding by re-testing in the given position. However, there is limited knowledge on repeatability of the response and its magnitude in both healthy normal population and individuals with balance disorder. To date, there has been only one study investigating this issue. Copperwheat (2005) tested 40 healthy normal participants using VNG and found only modest within session and low between sessions repeatability of the PN.

1.4 Positional nystagmus in healthy individuals

When assessing a dizzy patient by positional static test, it is essential to have normative data that help determine whether the patient's PN is caused by an underlying disorder or whether it is a result of normal variation. Currently, opinions of researchers are divided on whether PN can be manifested in an asymptomatic healthy individual (Barin, 2006; Copperwheat, 2005; Sunami et al., 2004; Levo et al., 2004; Bisdorff et al., 2000) or whether it always signifies an asymmetry in vestibular function (Roberts & Gans, 2008). Furthermore, even where researchers accept the existence of PN in healthy individuals, no general agreement exists in terms of the exact criteria for determining presence of pathological PN. This especially applies when static position testing is done using the VNG system, since a limited amount of normative studies have been conducted so far.

Finally, there is a problem with defining the concept of ‘normal healthy subjects’. There is not a clear consensus among authors in terms of the inclusion and exclusion criteria used in their studies. Since there is evidence that some drugs and non-otological diseases may result in increased incidence of PN (Sibony et al., 1987; Brandt, 1997; Koyuncu et al., 1999; Deutschländer et al., 2008; Pereira et al., 2000), it is possible that some individuals were wrongly included in the normative studies. This could have had affected results of those studies.

Traditionally, pathological PN has been defined as nystagmus without fixation with SPV that is greater than 6º/seconds (Barber & Stockwell, 1980). However, this limit has been based on measurements obtained with ENG technology, which does not allow precise measurement of vertical nystagmus, and which is potentially vulnerable to calibration drifts (Jacobson et al., 2008; Lightfoot, 2004). Since VNG technology has become widespread over the past years, normative data need to be obtained for these systems (Barin, 2008).

1.4.1 Prevalence

The reported prevalence of PN in normative studies using ENG was as high as 75% to 88% (Eviatar et al., 1970; Barber & Wright, 1973; McAuley et al., 1996), but also as low as 22% (Mulch & Lewitzki, 1977). In contrast, prevalence of PN was even higher in normative studies using VNG, ranging from 48% to 100% (Table 1.1). Table 1.1 summarises the seven reviewed normative studies using VNG and highlights differences in their methodologies. Since various criteria were used to determine presence of PN in those studies, as well as different test positions, direct comparison of results of these studies is difficult.

Table 2.1: *Summary of methodologies of the seven studies using VNG*

Author & year	Number (and age of subjects)	Number (and codes of positions)	Criterion for including PN into analysis	Prevalence of PN	Position provoking the highest rate of PN	Main flaws in methodology
Barin and Roth (un-published, cited in Barin, 2006)	40 (19-50)	6 (HU, BRS, BLS, C, CHR, CHL)	Not provided	Horizontal: 87% in at least 1 position. Vertical: 97% in at least 1 position.	Not provided	Speed of movements not defined. Not clear if only cases of persistent PN were included in data analysis.
Copperwheat, 2005	40 (2 groups: 20-35, 50-65)	**4x** 11(HR, HL, SHS, SHR, SHL,HH, HHR, HHL, BRS,BSL)	≥3 consecutive beats of PN within 30s.	100% in at least 1 position	BSL, HHL, SHS	No rationale given for the large number of tested positions.
Sunami et al., 2004	89 (25-40)	8 (C, CHR, CHL, BRS, BLS, HHS, HHR, HHL)	Not provided	73% in at least 1 position. Horizontal 46%, vertical 4.5%, mixed 2.2%	BLS, BRS	Speed of movements not defined. Spontaneous nystagmus (SN) test not conducted. Criteria for reporting PN not given. Mental alerting not used.
Levo et al., 2004	20 (13-56)	3 (SHS, , SHR, SHL)	≥5 consecutive beats of PN within 30s.	55% in at least 1 position.	SHR, SHL	Speed of movements not defined. Participants with SN not excluded from the study. Mental alerting not used.
Schneider, 2002	25 (23-60)	9 (HU, C, HHR,HHL, BRS, BLS,SHS, SHR, SHL)	≥3 consecutive beats of PN within 30s	48% in at least 1 position	HHL	Speed of movements not defined. Failed to conduct SN test. Only PN with SPV ≥6°included into data analysis. Mental alerting not used.
Bisdorff et al., 2000	18 (21-55)	5 (HU, SHS, SHL, SHR, P)	Not provided	100% in at least 1 position	SHS	Speed of movements not defined. Criteria for reporting PN not given. Mental alerting not used. Participants with SN not excluded from the study.
Geisler et al., (2000)	30 (3 groups: 20-39, 40-59, 60-80).	11 (C,HC, , HHL, CR, CL, SHS, SHL, SHR, HHR, RFD, LFD)	≥5 consecutive beats of PN within 30s	55% in at least 1 position	RFD	Speed of movements not defined. Failed to conduct SN test. Mental alerting not used.

1.4.2 Effects of age

There are conflicting findings regarding the effects of age on presence of PN in healthy individuals. Bisdorff et al. (2000) found no correlation between the age of the tested healthy individuals and prevalence of the PN. Even though Schneider (2002) observed the highest prevalence of PN (six out of nine test positions) in a participant in the older age range category, it was an isolated finding, and therefore not indicative of real age effects. While Geisler et al. (2000) reported the highest prevalence of PN in the older age category (60-80 years), the authors provided no further information whether this finding was statistically significant. Copperwheat (2005) did not find any significant differences in the PN prevalence and character between two groups of younger and older healthy participants. Statistically significant increases in both peak and average SPV measurements were found in the older group; however, this finding applied to only three test positions out of eleven.

1.4.3 Effects of gender

A number of studies investigated the effects of gender on the incidence of PN in normal healthy individuals. The results of these studies were consistent with each other showing no significant effects of gender on incidence of PN (Copperwheat, 2005; McAuley et al., 1996; Geisler, 2000, Bisdorff et al., 2000).

1.4.4 Outcome of normative studies using videonystagmography

Since outcomes of normative studies using ENG systems have been described in great detail elsewhere (Copperwheat, 2005), the following overview includes only those studies that used VNG technology as a way of monitoring eye movements.

Barin and Roth (unpublished, as cited in Barin, 2006 and in Barin, 2008)

An unpublished study by Barin and Roth (as cited in Barin, 2006 and in Barin, 2008) focused on obtaining normative data for horizontal and vertical nystagmus. In this study, 40 individuals aged 19 to 50 years underwent static position testing using VNG in six positions. These were HU, C, CHR, CHL, BRS, and BLS from Figure 1.6.

Out of these 40 participants, 35 (87%) demonstrated horizontal PN in at least one test position and three participants had PN in all test positions. Nine participants displayed horizontal geotropic PN (n=4) or ageotropic PN (n=5) with a change in a head position. No one participant had horizontal PN with fixation. Furthermore, 39 out of the 40 tested individuals (97%) displayed vertical PN in at least 1 position and six of these had PN in all test positions. The 95% confidence interval (CI) of average maximum SPV of the horizontal PN was found to be 5.4°/s, which is a finding nearly identical to currently accepted cut-off point for pathological PN used with the ENG systems. For this reason Barin and Roth suggested that 6°/s should remain a threshold for determining of pathologic PN. The researchers also obtained normative data for vertical PN. In their study, vertical PN was even more frequent finding than horizontal PN (97% versus 87%). With 95% CI the average maximum slow phase velocity was 9.9°/s. Therefore, Barin and Roth suggested setting the threshold for pathological vertical PN at this level. It is worth noting, that these data were later reviewed by the first author and the threshold for pathological horizontal and vertical PN were redefined as 4°/s and 7.7°/s, respectively (Barin, 2008).

Since this study has not been published yet, some details with regards to methodology and results are unclear. Firstly, it is not obvious to a reader how two different sets of thresholds for pathological PN could have been obtained. Furthermore, while the authors argue that intermittent PN is related to technical issues and should not be used as a parameter for identifying pathological PN, they do not clearly specify whether cases of intermittent PN were included in the data analysis. It is also not apparent which position provoked the highest incidence of PN. This information would have been useful to compare effectiveness of different test positions for eliciting PN.

Copperwheat (2005)

Copperwheat (2005) investigated prevalence and repeatability of PN in 40 healthy participants with no history of otological disorders or dizziness, and with pure tone hearing thresholds appropriate to their age. Apart from obtaining normative data, the study also intended to identify the effects of age and gender and review the suitability of the criteria of Shepard and Telian (1996) for the use with VNG. Copperwheat (2005) divided the recruited cohort into two groups according to their age. The younger group consisted of individuals aged 20-35 and the older group consisted of individuals aged 50-65. Equal numbers of female and male were present in each group. In total, four sets of positional testing were conducted on two separate occasions (two sets per one day) to explore within sessions and between sessions repeatability. The two main sessions were spaced one week apart and five minutes breaks were provided for the within session testing. Eleven positions were used for the static positional testing. These were HR, HL, SHS, SHR, SHL, HH, HHR, HHL, BRS, and BSL as shown in Figure 1.6. The choice of these positions was based on recommendations of Shepard and Telian (1996). Positional nystagmus was deemed present if at least three consecutive beats of PN could be identified. No rationale was given for this criterion.

The static position test elicited PN in all participants (100%) in at least one test position in at least one out of four test sessions. Twenty six participants (68%) had PN in at least one position in three sessions, five participants (13%) had PN in at least one position in two sessions, and two participants (5%) had PN in at least one position in one session. Each position provoked PN in at least one participant. The highest prevalence of PN averaged across all four sessions occurred in the BSL, HHL, and SHS positions (60%, 55%, and 50%, respectively). The lowest rate of PN occurred in the HR and HL positions. There was a clear predominance of horizontal left-beating PN (57.7% of all the cases of PN), being followed by horizontal right-beating and vertical down-beating PN, which both had prevalence of 16.8%. Sporadic PN was observed twice as more often as persistent PN. The lowest measured average SPV was 0.6°/s and the highest was 10.0 °/s. However, separate information about the ranges of the SPVs of the vertical and horizontal PN was not provided. As the SPVs of all valid cases of the PN were analysed together regardless of its direction (i.e. horizontal, vertical, and oblique), this study provided limited benefits in terms of establishing normative data with use of VNG. Furthermore, the within and between session repeatability was shown to be only modestly and weakly related, respectively, suggesting low repeatability of PN. Furthermore, no effects of gender were found in this study. No significant differences were observed between the two groups in terms of the prevalence and character of the recorded PN. While some older participants had down-beating vertical PN that was not observed in the younger group, this finding was not statistically significant. Significant differences were however found in relation to average and peak SPVs in the BRS, BLS, and C positions, in which the older group displayed significantly greater SPV magnitudes than the younger group. While this study had some limitations in terms of data analysis, it had a sound design compared to other reviewed studies. For this reason it could be easily and accurately replicated.

Levo et al. (2004)

Levo et al. (2004) evaluated reliability of a VNG system in detecting spontaneous, positional, and head-shaking nystagmus in 20 healthy participants with no history of vertigo, balance problems, otological diseases, or neurological disorders. Their age ranged from 13 to 56 years. The study focused on static positional testing only marginally, using just three test positions from Figure 1.6: SHS, SHR, and SHL. A minimum of five consecutive beats within a 30 second period were required in order to report presence of PN, however no rationale for this criterion was provided. Lateral head turns were repeated six times, each head turn being followed by 15 seconds long recording. The authors stated they chose this design in order to study BPPV of the horizontal SCC; however, no information about the speed of the movements was provided by the authors. Since slow speed of movements is necessary for static position testing, this could mean that the observed nystagmus was not in fact positional but positioning. This is even more suggestive given the fact that only 15 seconds long recordings were obtained after each head turn. This may not have been a long enough period for a true PN to develop fully.

The overall prevalence of the observed nystagmus was 55%. The SHS position elicited nystagmus in four participants, out of whom one had horizontal, one vertical, and two had both the horizontal and vertical nystagmus. The SHR and SHL elicited nystagmus in eight participants, out of whom five participants had horizontal, one vertical, and one had both horizontal and vertical nystagmus. It was not reported whether any participant had nystagmus in more than one position. It is worth noting that the testing did not provoke any incidences of torsional nystagmus, which would have been expected if the observed nystagmus was of a positioning character. Furthermore, the SPV for the nystagmus was low across the participants, ranging from 0.5 to 5°/s with mean of 1.7 °/s. Finally, since four participants (20%) were found to have low magnitude SN (1-2 °/s), and no detail was given on whether these participants were excluded from further testing, it is possible that this may have affected the results. This notion can also be supported by the fact that no information about the direction of the reported PN was reported. Since it is a known fact that SN is typically direction-fixed (McCaslin et al., 2008), this could have given at least some indication about the true character of the observed nystagmus.

Sunami et al. (2004)

Sunami et al. (2004) investigated prevalence of positional and positioning nystagmus in 89 healthy participants. Sixty one males and 28 females aged 25 to 40 years with no history of vertigo, otological disorders, or central nervous diseases were included in the study. In total eight positions were used for positional static testing. These were HHS, HHR, HHL, BRS, BLS, C, CHR, and CHL from Figure 1.6. Positional nystagmus was detected in 65 out of the 89 participants (73%). The character of the PN varied across the tested participants, including direction-fixed (n=30) and direction-changing (n=11) horizontal PN, vertical PN (n=4), and 'mixed torsional' PN (n=2). Each test position elicited PN in at least one participant. Positional nystagmus was present in more than four positions in 36 participants (40%) and in all eight positions in seven participants (8%). The highest rate of PN occurred in the BRS position (n=41), being closely followed by the BLS position (n=38). In fact, 42.7% of the participants demonstrated PN in the former position. However, closer inspection of the data shows that all positions had similarly high provocation rates and therefore it is not clear whether the increased prevalence was statistically significant. Furthermore, this study does not provide any detail about the criteria used for deciding presence of PN. Similarly, it is not known whether the participants were tested for presence of SN prior to the start of the static position test. For this reason it is possible that some of the reported cases of the PN could have been in fact cases of SN. Finally, no information was given about the average and maximum

SPVs of the reported PN. For this reason, no benefit can be derived from this study in terms of determining the threshold for pathological PN.

Schneider (2002)

Schneider (2002) examined 25 healthy participants aged 23 to 60 years for presence of PN in nine test positions. These positions were HU, C, HHR, HHL, BRS, BLS, SHS, SHR, and SHL from Figure 1.6. Positional nystagmus was considered present if at least three or more consecutive beats of intensity at least 6°/s occurred within 30 seconds. Prevalence of the PN was 48%, with each test position eliciting PN in at least one participant. Two participants had PN in more than three test positions. No participant manifested PN in all test positions. The highest prevalence of PN occurred in the HHL position (2% of all valid cases of PN) and the smallest prevalence occurred in the SHR and SHS positions. The paper did not state whether these differences were statistically significant. Furthermore, no detail is provided on the character of the observed PN. It is interesting to note that even though this study aimed to investigate prevalence of PN in healthy participants, only PN greater than 6°/s was included in the analysis. This limit is usually considered as a cut-off point for pathological PN. Therefore, since 48% of the tested cohort was found to have PN greater than 6°/s, the results of the study would in fact suggest that nearly half of the studied individuals had some kind of underlying pathology. This is however very unlikely, since none of the tested individuals had a history of dizziness or otological disease. Furthermore, by not reporting the cases of PN where the intensity was smaller than 6°/s, this study has not contributed to obtaining normative data for pathological PN. It would be interesting to know what the average maximum SPV of the PN was across the tested individuals.

Bisdorff et al. (2000)

Bisdorff et al. (2000) assessed horizontal and vertical components of PN in 40 healthy participants. However, only 18 out of 40 participants underwent typical static positional testing. Five test positions from Figure 1.6 were applied and these were HU, SHS, SHL, SHR, and prone (P). In two more experiments that took place within the main investigation, technically complicated, and potentially clinically irrelevant, tests were carried out, using 3-D flight stimulators and a linear accelerometer. These were looking at modulation of vertical nystagmus with pitch angle and effects of static pitch angle on eye movements. While the study reported 100% prevalence of PN in all 18 subjects in at least one position, it did not provide any detail with respect to the criteria used for determining presence of PN. Furthermore, the study did not elaborate on the PN character and intensity, apart from a rudimentary statement that horizontal, vertical, and oblique nystagmus had been observed. No information was given about whether any subjects had nystagmus in more than one position and which position provoked the highest in rates of PN. Review of the raw data however showed that the SHR, SHL, and P positions elicited nearly equal prevalence of PN (13, 14, and 14, in that order) in the tested participants. The HU and SHS positions provoked the lowest and highest incidences of PN (10 and 17, respectively). Furthermore, the study did not mention whether mental alerting was used throughout the testing, the duration of recordings in each position, and the speed of movement between positions. Finally, since the study did not clearly differentiate between SN and PN, there may have been some cases of misidentification of PN.

Geisler et al. (2000)

Geisler et al. (2000) examined a cohort of 30 healthy participants, in which male and female were equally represented. After excluding one participant, who was suspected to have a central disorder, the study group was divided according to their ages into three following groups: group A (20-39 years), group B (40-59 years), and group C (60-80 years). All groups underwent positional and positioning testing under 11 positions (Table 1.0). These also included two, right and left, 'forward Dix-Hallpike' positions. For example, the right forward Dix-Hallpike (RFD) position entailed moving a patient from the usual Dix-Hallpike position, where the patient lies supine on an examination couch with their head hanging and turned to the right, to a sitting position and leaning them forward toward the right knee while maintaining the head turned 45 ° to the right. Following this logic, the left forward Dix-Hallpike (LFD) positions required sitting the patient up from the LHH position and leaning them forward towards the left knee while maintaining the head turned 45 ° to the left.

Geisler et al. (2000) explained the use of these positions as a complementary test for the vertical SCCs. Measurements started after the participant was moved into a new position and lasted for 30 seconds. Positional nystagmus was reported when five or more consecutive beats were detected. The study reported prevalence of PN in 16 out of the 29 tested participants (55%) in at least one position. Eight participants were found to have PN in more than two positions. The RFD position elicited the highest rate of PN, being followed by LFD and HHL positions. The PN had higher prevalence in the eldest age group; however, it is now clear whether the difference was statistically significant.

This study was lacking in some areas. Firstly, while the authors referred to observed nystagmus as PN, it is not clear from their methodology whether the position test was static or dynamic, since the speed of movements from one position to another was not reported. It is however interesting that no cases of torsional nystagmus, which is a typical finding during Dix-Hallpike manoeuvre due to BPPV of the vertical SCCs, were recorded despite the high prevalence of PN among the tested participants. However, since none of these individuals had any history of dizziness or vertigo, this would indeed suggest that the observed nystagmus could have been of a true positional character. The authors especially noted that RFD and LFD positions, which were supposed to stimulate the vertical SCCs, provoked horizontal or oblique nystagmus instead of torsional. Such a finding would mean that the PN was not caused by stimulation of the vertical SCCs. The authors concluded that this may have occurred due to the head not being stable in that position. This suggestion is consistent with the fact that six out of 15 participants who displayed PN in the LFD and RFD positions had no PN in other positions. Furthermore, since the study probably integrated dynamic positioning into the 11 tested positions, the results did not reflect accurate information about prevalence of PN in healthy participants. If only results of strictly static positional testing were included, the prevalence of PN would have decreased to 17% (five out of 29 participants). Finally, since this study used rather loose criteria for determining presence of PN, and did not report the magnitude of the SPVs, the findings did not contribute in any way to establishing a threshold for pathological PN.

1.5 Pathological positional nystagmus

1.5.1 Aetiology

The exact mechanism of pathological PN remains unknown; however, it is believed that the PN may occur as a result of abnormal interaction between SCCs and the otolith organs or the central vestibular pathway (Roberts & Gans, 2008). Barin (2006) stipulated that even though the SCCs are not sensitive to gravity, their vestibular afferents merge together with those of the otolith organs to form the vestibular portion of the eight nerve. Therefore, the PN could arise as a result of the shared neural pathways. In contrast, Shepard and Telian (1996) suggested that pathological changes in the SCCs could make the canals gravity-sensitive, resulting in the manifestation of PN.

Positional nystagmus can also occur as a result of a central lesion (Brandt, 1990). This can be due to drug intoxication, multiple sclerosis, degeneration, a tumour, or an infarction of the cerebellum or the brain stem (Pierrot- Deseilligny & Milea, 2005). The central lesion may or may not be accompanied by vertigo (Roberts & Gans, 2008). Furthermore, conditions such as migrainous vertigo have also been suggested to provoke PN (Von Brevern et al., 2004; Roberts & Gans, 2008).

It has been argued that PN provides ‘non-localising’ information (Brandt, 1997; Shepard & Telian, 1996). This would mean that the PN has a limited value in terms of differentiating central and peripheral lesions and the side of the lesion. However, current literature suggests that the removal of visual fixation enables differentiation between vestibular and central lesions (Roberts & Gans, 2008; Barin, 2006; Maire & Duvoisin, 1999). Maire and Duvoisin (1999) tested this hypothesis and found out that the optical fixation index (OFI), which is a ratio between the mean SPV with and without fixation, had a good predictive value for differentiating a peripheral vestibular lesion from a central lesion. According to Barin (2008), nystagmus without fixation, either horizontal or vertical, suggests a vestibular lesion and nystagmus with fixation suggests a central lesion. However, there is an exception in the form of cupulothiasis of the horizontal SCC, which can manifest as PN rather than positioning nystagmus. In this case the PN often persists even with fixation (Roberts & Gans, 2008). While

Roberts and Gans (2008) suggest that in peripheral lesion the PN beats towards the intact ear, evidence is lacking to support this presumption.

1.5.2 Criteria

A number of different criteria for determining abnormal PN have been defined in literature. Most of these have been based on the ENG technology, which does not take vertical PN into consideration.

According to Barber and Stockwell (1980), horizontal nystagmus without fixation would signify a vestibular pathology if one of the following criteria were fulfilled:

1. Nystagmus (intermittent or persistent) with SPV >6°/s in any head or head and body position.
2. PN with SPV <6°/s, but persistent in three or more head or head and body positions.
3. Intermittent PN with SPV< 6°/s in four or more head or head and body positions.

More recent diagnostic criteria come from Shepard and Telian (1996). The researchers suggested that clinically significant PN should fall under one of these categories:

1. PN (intermittent or persistent) with SPV >5°/s.
2. PN with SPV <6°/s, but persistent in four or more out of eight to 11 positions.
3. Intermittent PN with SPV < 6°/s, but present in all test positions.
4. Direction-changing PN, which changes its direction within a single head/or head and body position.

The diagnostic criteria by Shepard and Telian (1996) were revisited by Copperwheat (2005) who investigated prevalence of horizontal, vertical, and oblique PN in healthy normal individuals using VNG. Based on her own normative data, the researcher's recommendations for determining presence of abnormal PN were as follows:

1. PN (intermittent or persistent) with SPV >6°/s.

2. Persistent PN with SPV <6°/s, which is present in at least five or more positions of the 8-11 positions.
3. Intermittent PN with SPV <6°/s, but present in all test positions.
4. Direction-changing PN within a given test position.

However, Copperwheat (2005) based the new diagnostic criteria on averaged peak SPVs of all cases of PN, regardless their character (horizontal, vertical, and oblique). Since no detail was provided on separate SPV ranges of horizontal, vertical, and oblique PN, it is not certain whether the criteria can be accurately applied to all types of PN.

A study by Barin and Roth (unpublished, cited in Barin, 2006) also attempted to outline new diagnostic criteria in conjunction with VNG. The researchers found different limits for determining pathological PN for horizontal and vertical PN. These were 4°/s and 7.7°/s, respectively. Thus, this suggests that different types of PN may require separate diagnostic criteria.

Furthermore, since the recommendations of Shepard and Telian (1996) and Copperwheat (2005) are based on the use of at least eight test positions, those criteria cannot be applied where a clinician uses fewer than eight test positions. Since there is no unity among researchers in terms of the number of positions used, Barin (2006) proposed that only magnitude of the observed PN should serve as a tool for determining presence of pathological PN. This is especially a valid argument given the fact that even very low magnitude PN could achieve clinical significance under the criteria of Shepard and Telian (1996). Furthermore, since there is no clear definition in the literature regarding what constitutes intermittent and persistent PN, the persistence of the PN should not be used as a sole criterion for defining presence of pathological PN.

1.5.3 Effects of stimulants and other disorders

1.5.3.1 Positional Alcohol Nystagmus

Direction-changing PN can be manifested after consumption of alcohol. The positional alcohol nystagmus (PAN) occurs in three phases (Brandt, 1997). The first phase, PAN I, which occurs within 30 minutes after alcohol digestion, represents diffusion of alcohol into the cupula. This happens when the ethanol blood level is at least 40 mg/dL. Since alcohol is lighter than endolymph, the cupula becomes lighter relative to the surrounding endolymph, making the SCCs sensitive to gravity. The PAN is geotropic at this stage. This means that the PAN beats towards the undermost ear. Three to five hours later a 'silent' period occurs. During this phase no nystagmus is present as alcohol diffuses also into the endolymph, resulting in equal specific gravity of the cupula and the endolymph. In the third phase, PAN II, which occurs after approximately five to 10 hours, alcohol leaves the cupula, but remains in the endolymph. This results in the cupula becoming heavier. The resultant nystagmus is ageotropic, which means beating towards the uppermost ear. Positional vertigo is often present throughout all PAN stages and does not cease until alcohol leaves the endolymph altogether (Brandt, 1997).

1.5.3.2 Nicotine

There is increasing evidence suggesting that nicotine can provoke PN. Sibony et al. (1987) investigated the effects of nicotine on eye movement using ENG and a magnetic search coil technique. They reported incidence of transient upbeat nystagmus lasting up to 20 minutes. Similarly, Pereira et al. (2000) reported incidence of nicotine-induced nystagmus (NIN). In their study 27 out of 53 tested individuals (51%) displayed NIN after inhaling tobacco smoke. Pereira et al. (2000) concluded that nicotine induces imbalance in the VOR. Deutschländer et al. (2008) investigated pathogenesis of nicotine-induced nystagmus (NIN) by making eight healthy participants smoke during magnetic resonance imaging. Their eye movement was monitored using the VNG. The researchers discovered that the NIN was triggered at the level of the midpontine in the brainstem.

1.5.3.3 Otitis Media with Effusion

Koyuncu et al. (1999) investigated effects of otitis media with effusion (OME) on vestibular system in children. The study involved 30 children with OME aged 8 to 13 years. A battery of vestibular tests including static positional testing was performed on these children, and their results were compared to those of 15 healthy age- and gender- matched children. Ten of the children with OME had a history of balance problems (33%) and the same number displayed PN during the static positional testing. However, there was no correlation between the vestibular test results and the enquiry of the balance problems. The detected PN was horizontal transient and direction-fixed, with SPV exceeding 7-8 °/s, which according to Barber and Stockwell (1980, as cited in Barin, 2006) signifies a pathological finding. No pathological PN was found in the control group; however, no indication is given as to whether any PN at all was detected in this group. After the baseline measurements were completed myringotomy with grommets insertion was carried out. A second set of identical tests was performed within the first month after the surgery. On this occasion no PN was detected in those children. The findings of this study suggest that fluid behind the tympanic membrane (TM) can significantly affect balance in one third of children with OME. According to Gates (1980, as cited in Koyuncu et al., 1999), this occurs as a result of pressure changes within the middle ear cavity due to the build up of the fluid, causing the displacement of the round window and consequently secondary perilymphatic movement.

1.5.3.4 Metabolic disorders

Metabolic disorders, such as diabetes mellitus (DM), can seriously impact on the function of the nervous system. The affects are variable, depending on the duration of the illness to a certain degree. It has been previously suggested that diabetic neuropathy can affect hearing (Friedman et al., 1975); however, no evidence concerning peripheral vestibular system has been available until recently. Gawron et al. (2002) examined 95 children and young adults aged from six to 28 years with insulin-dependent diabetes mellitus (DM) to determine the effects of their illness on the vestibular system. Out of these only six individuals complained of balance problems. Forty-four age-matched healthy participants were recruited as a control group. Positional nystagmus was found in 21 individuals with DM out of whom six had persistent direction-fixed PN, five had persistent direction-changing PN, and ten had intermittent PN. Only one individual from the control group displayed PN, which was of a persistent direction-changing character. However, no detail was given as to which head position elicited the PN. The prevalence of the PN in DM group was positively correlated with the duration of DM.

1.6 Summary of the current knowledge

The review of the literature on static position testing suggests that despite the advances in technology for recording eye movements, there are still some gaps in present knowledge. While it is apparent that PN does occurs in normal healthy population, the exact prevalence is unknown due to inconsistencies in the studies investigating this subject. For the same reason consistent normative data for PN is not available with the use of VNG. The lack of the normative data is especially palpable when assessing the vertical PN, for which no normative data has been published until today. There is also limited evidence on the effects of mental alerting on PN. If mental alerting has a real effect on the manifestation and magnitude of the PN, it should become an inseparable part of the static position test (Takahashi et al, 1996; Barin, 2006). Furthermore, there is some doubt about repeatability of the PN. This is potentially an important factor to consider, since a clinician may want to repeat testing in those positions where PN was manifested (Copperwheat, 2005). Finally, no consensus has been reached on the number and type of positions used in the static position testing. The reviewed studies show inconsistent results in terms of which test positions produce the highest rates of PN. This is mainly due to the fact that different numbers and types of head and body positions were used in those studies.

CHAPTER 2- METHODS

2.0 Aims of the current study

The review of literature on static positional testing has highlighted a number of areas in need of investigation. The present study aims to answer the following questions:

- Does mental alerting increase prevalence and magnitude of PN in normal healthy population?
- Is PN repeatable for a particular position within the same test session?
- Is there a difference in PN prevalence rates across different head and head and body positions?

2.1 Hypothesis

- Mental alerting increases prevalence and magnitude of PN in the normal healthy population.
- There is a weak test-retest within session repeatability of PN in the normal healthy population.
- There is no one test position that can generate consistently the highest rates of PN in the normal healthy population.

2.2 Design

The present study investigated prevalence of PN in normal healthy participants using VNG. Three main variables were examined: the effects of mental alerting, within session repeatability of PN, and prevalence of PN across different head and body positions. The experiment consisted of four identical sets of static positional testing that were carried out during one test session on the same day. Short breaks (5-10 minutes) were allowed between the test sets. In each of these sets participants underwent examination in 11 head and body positions. Two of these sets were conducted with mental alerting and two sets without mental alerting. This was done in order to assess the effects of mental alerting, as well as within session repeatability. The Latin square was used to randomise the order in which different head and body positions were tested. The aim of this was to eliminate any potential order effects. For the same reason the order of the test sets with mental alerting and with no mental alerting were randomised.

2.3 Sample selection

2.3.1 Sample size

Using the Sample Power software package it was calculated that 18 participants would be required in order to achieve statistical power of 80%. This sample size would provide sufficient effect size of 2°/s when assessing effects of mental alerting versus no mental alerting in the same group of participants.

2.3.2 Participants

For the purposes of this study, participants were recruited from amongst postgraduate students of the University Southampton and personal acquaintances of the author. The potential participants were approached via email or personally. Thus a non-random sampling method was used for recruitment of participants. In total, 24 participants were recruited, two of whom were excluded due to presence of first degree SN. Data of further four participants were discarded due to insufficient quality of their VNG recordings. Hence, only eighteen out of 24 recruited participants completed the experiment and their data were included in the final analysis. Five participants were male and 13 participants were female. Their ages ranged from 22 to 76 years (mean=36.5, median= 25.5, standard deviation (SD)= 17.1) (Figure 2.0).

2.3.3 Inclusion criteria

Only otologically normal participants with no history of otological disorders, dizziness, neck or back problems, and cardiovascular problems were eligible to participate in this study. These criteria were assessed via medical questionnaire (Appendix A) and screening tests, consisting of otoscopy, tympanometry, and pure tone audiometry (PTA).

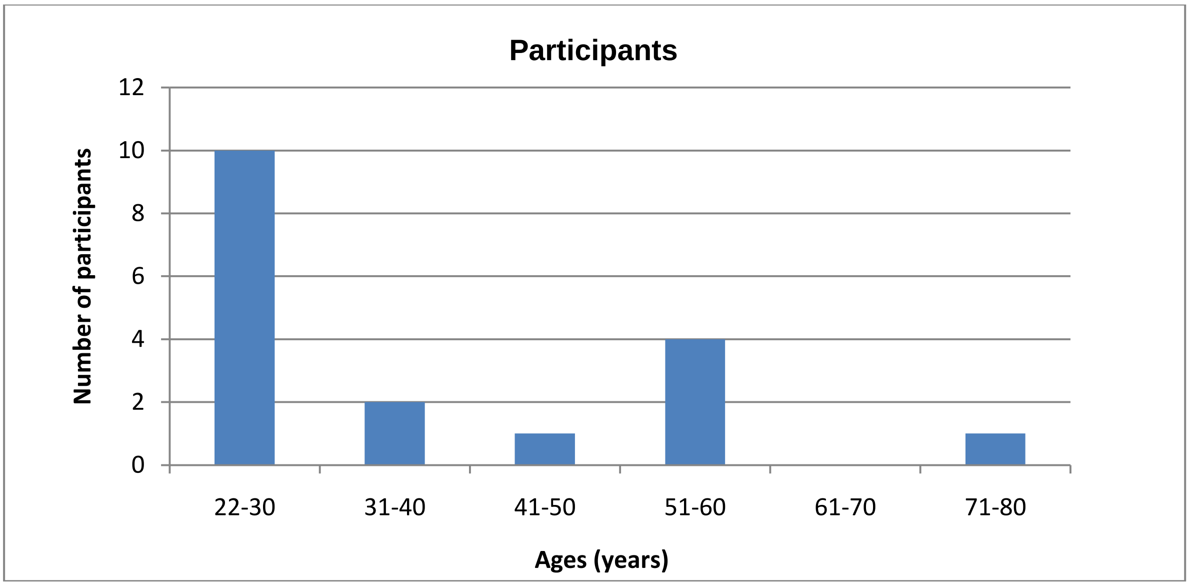

Figure 2.0: *Age distribution across the recruited group of participants.*

2.3.4. Exclusion criteria

Participants were excluded from this study if they were found to have SN of any degree and magnitude during the spontaneous nystagmus test and/or did not fulfil the inclusion criteria.

2.4 Equipment

2.4.1 Equipment for screening

- Otoscopy- Heine Mini 2000 otoscope with disposable specula
- Tympanometry- GSI Tympstar Middle Ear Analyser
- GSI Test Cavity 2000-1036 for GSI Tympstar
- Pure Tone Audiometry- GSI 61 Clinical Audiometer coupled to TDH-50P Supra Aural headphones and bone vibrator B71

2.4.2 Equipment for static positional testing

- Computer with VNG CHARTR software for Windows- ICS Medical system
- Light- bar coupled to the VNG system
- VNG goggles- ICS Medical
- Standard vestibular examination table with adjustable height and head support

- Pillow

2.4.3 Test room

All testing was carried out at the Institute for Sound and Research Vibration (ISVR) at the University of Southampton. The static positional testing was conducted in the Vestibular Room and the screening tests in the Skills Laboratory at the ISVR.

2.5 Calibration

2.5.1 Calibration of equipment for screening

It was verified that the audiometer had undergone annual calibration (stage B check) in accordance with BS EN 60645-1 (IEC 60645-1) standard in September 2009. Stage A checks, as recommended by British Society of Audiology (British Society of Audiology, 2004), were carried out daily prior to the start of testing. The stage A checks involved subjective listening to sweeps of just audible tones of 10 dB HL across frequencies 250-8000 Hz for the earphones and 500-4000 Hz for the bone vibrator. A similar procedure was carried out for the high-level tones, where air conduction was verified using a sweep of tones of 60 dB HL for air conduction and 40 dB HL for bone conduction.

The tympanometer had undergone annual calibration in November 2011. Its proper functioning was also verified daily prior to the start of testing by measuring recorded volume in 2 cc GSI test cavity.

2.5.2 Calibration of equipment for static positional test

For individual calibrations of the VNG system, participants were positioned on the examination table sitting upright with their legs out and facing a light bar. The back support of the table was raised in order to ensure that the participants were in a stable and secure position on the table. Whenever required, the height of the table was adjusted in order to align the participants’ eyes with the light bar. Conjugate eye movement was examined by asking the participants to follow the tip of the examiner’s index finger as it was moved slowly in horizontal and vertical planes. Videonystagmography goggles were carefully placed on the participants’ heads as not to cause any damage to their faces. The elastic band of the goggles was tightened to a comfortable level in order to prevent the goggles from slipping. Once the correct and comfortable placement of the VNG goggles was achieved, the front cover of the goggles was removed. An acceptable distance (4 feet, +/- 2 inches) between the participant and the light bar was verified by selecting the ‘Range’ on the CHART VNG program. The examination table was moved back or forth whenever an adjustment to the position of the table was required. In order to achieve the clearest possible recording, the VNG goggles were adjusted for each subject individually by selecting the ‘Video adjust’ button. Participants were asked to look to their right, left, up, and down, while their eyes were being viewed on the computer screen. Changes in brightness and contrast levels were carried out whenever necessary. Further to this, the orientation of the VNG goggles’ mirrors was adjusted in cases where there was a difficulty in achieving an optimal contrast between the participant’s pupils and surrounding facial tissues. Following this, the participants were instructed to follow movement of the light on the light bar as smoothly and accurately as they could with their eyes, while keeping their heads still. The VNG system was calibrated using the ‘smooth pursuit’, with the horizontal channel being calibrated first and the vertical channel second.

2.6 Pilot study

The pilot aimed to ensure safe practice and highlight any areas in need of attention. Three female participants took part in the pilot study, all of whom were postgraduate students of Audiology. Following the screening tests, each participant underwent four sets of static positional testing, one with mental alerting and one without. This provided an effective mechanism for refining the key issues. These were:

1. CHARTR VNG software
2. Participants’ safety
3. Goggles placement
4. Participants’ positioning
5. Mental alerting
6. Speed of movement
7. Time requirements

The CHARTR VNG software was found to be insufficiently equipped to provide ‘codes’ for as many as 11 head and body positions. For this reason, when recording eye movements in the 11 positions, alternative codes had to be used. For example, the ‘sitting position with head turned left’ had to be coded as ‘sitting with vision’, while the ‘sitting position with head turned right’ had to be coded as ‘sitting without vision’. In order to prevent later incorrect data entry, a printed chart with the 11 depicted test positions was obtained and the substitute codes were plotted against the different test positions.

As the participants were tested with vision removed, and a large number of head and body positions were examined in one test set, it was necessary to provide a safe mechanism for the participants’ movements. Initially, arm supports were put in place to establish the lateral boundaries of the table; however, these were found to be unsteady and for this reason were removed. Instead, the participants were instructed to wait for the tester to tell them which test position would be tested next and then they were gently guided into position.

Each test set involved placing a participant into 11 different head and body positions and for this reason it was important to achieve a comfortable, yet stable, fitting of the VNG goggles throughout the testing. This proved to be a challenging task, especially when working with female participants with long hair, in whom the band of the goggles tended to slide down. The problem was resolved by asking those participants to put their hair into a ponytail against which the headband could rest. The tightness of the headband was adjusted individually so as to respect the participant’s head shape and prevent the goggles from moving, yet maintain the participants’ comfort.

The pilot test also revealed a problem with the goggles alignment in the ‘body right side’ and ‘body left side’ positions. The goggles tended to be pushed in the opposite direction to the side the participant was lying on. This problem was resolved by placing a pillow underneath the participants’ heads.

As majority of the participants were postgraduate University students, it was recognised that a sufficiently challenging task would be necessary to keep them mentally alert. Therefore participants were asked to start counting backwards from 1000 in fours (in those test sessions where mental alerting was indicated) as soon as they were placed into a new test position, and they were asked to continue counting for as long as they were kept in the test position. Participants were reminded before each test session whether the forthcoming session involved mental alerting. In order to verify that participants were performing their task, they were asked randomly once or twice per position about the progress of their counting.

Whilst a metronome was used in a previous study to guide the speed between positions during the test (Copperwheat, 2005), this tool was not found useful in this experiment. The participants in the pilot study felt that the metronome was confusing them rather that assisting them in position changing. Furthermore, it was believed that the results of this experiment should be applicable to a typical clinic setting. For this reason, the participants were simply instructed to move from position to position in a slow and even manner.

The pilot study demonstrated that a minimum of 90 minutes are required per participant to complete the medical questionnaire, screening tests, and the four sets of static positional testing. During the pilot study it was also recognised that short breaks between the test sets may be necessary in order to maintain participants' comfort.

2.7 Procedure

2.7.1 Screening

Prior to the start of the testing the recruited participants were given an information sheet, which was providing details about the purpose and design of the test (Appendix B). Once familiar with the test, the participants were asked to complete a medical questionnaire and sign a consent form (Appendix C). The participants were advised that they could withdraw from the experiment at any time without providing a reason.

- Health questionnaire

The questionnaire (Appendix A) consisted of 12 questions concerning balance, hearing, otological disorders, eyesight, neck or back problems, mobility problems, cardiovascular problems, general health, smoking and drinking habits, and the use of any drug. Questions related to balance aimed to reveal any past episode of vertigo, which would disqualify the participant from the study. Questions related to hearing aimed to identify participants who were aware of hearing difficulty and whose hearing loss was likely to be outside the age-related normative data (International Organization for Standardization, 1984). These participants would not be eligible to enter the study, as there is a body of evidence suggesting that hearing disorders are positively correlated to subclinical balance disorders (Ylikoski et al., 1988; Shupak et al., 1994). Questions related to otological disorders aimed to identify individuals with recurrent ear infections, discharge, and OME, in whom these conditions could affect results of the static positional test (Koyonuc et al., 1999).

Questions related to eyesight aimed to identify individuals with eye condition that could result in disconjugate eye movement or inability to follow the light on the light-bar during calibration and spontaneous nystagmus test. Questions related to neck or back problems intended to identify individuals for whom testing would be contraindicated due to positioning the head and the body on the examination table (British Society of Audiology, 1992a). Three older participants had previously experienced some low level neck or back pain; however, none of them felt this would prevent them from participating in this study. Questions related to cardiovascular problems and general health aimed to ensure that participants were free of any serious health condition that could put them at risk if taking part in the experiment.

Finally, questions related to smoking, drinking and the use of the drugs aimed to identify individuals in whom PN could be elicited as result of smoking, drinking or taking drugs. One younger participant (22 years) admitted to consuming two units of alcohol 15 hours prior to the start of testing. One older participant (76 years) admitted to consuming three units of alcohol 17 hours prior to the testing. In both cases the participants consumed a relatively small amount of alcohol and there was a sufficiently long time between the alcohol consumption and the testing for the PAN

II not to occur (Brandt, 1997). For this reason none of these participants were excluded purely on this basis.

- Otoscopy

Bilateral otoscopy was performed on each participant to detect any abnormality, including excessive wax, infection, perforation, or discharge. One of the participants was found to have perforated tympanic membranes bilaterally. However, these perforations were small and dry, the participant's hearing remained within normal limits, and therefore the participant was not excluded from the study.

- Pure Tone Audiometry

Pure tone audiometry (PTA) was performed in accordance with the British Society of Audiology (BSA) recommended procedure (British Society of Audiology, 2004). As six participants were older than 50 years, age-related normative data were used to verify whether their hearing thresholds fitted into the normal range (International Organization for Standardization, 1984). All participants were found to have hearing within normal limits.

- Tympanometry

Bilateral tympanometry was carried out and interpreted according to the BSA recommended procedure (British Society of Audiology, 1992b). All participants had results within normal limits. In the participant with the bilateral perforations tympanometry was not conducted as not to cause any discomfort.

- Spontaneous nystagmus test

Spontaneous nystagmus test was carried out for each participant once the VNG system was calibrated horizontally and vertically. Spontaneous nystagmus test was conducted with vision open and with vision denied in three gaze positions: eyes centre, eyes right, and eyes left. Mental alerting task, identical to the one used during static positional testing, was carried out throughout the test. During the SN test two participants were found to have clinically non-significant first degree SN (SPV less than 6°/s) and for this reason were excluded from this study.

2.7.2 Static positional testing

All four test sets were carried out during one main test session on the same day. Five to ten minute-long breaks were provided for the participants between test sets. An individual test set consisted of the following 11 test positions presented in a randomised order:

1. Sitting head turned right (HR)
2. Sitting head turned left (HL)
3. Supine head straight (SHS)
4. Supine head turned right (SHR)
5. Supine head turned left (SHL)
6. Head hanging straight (HHS)
7. Head hanging right (HHR)
8. Head hanging left (HHL)
9. Body right side (BRS)
10. Body left side (BLS)
11. Caloric test position (C)

Prior to the start of testing, participants were informed about the order of the head and body positions in the forthcoming test set, as well as whether the test set would involve mental alerting. Furthermore, throughout the testing the participants were informed about each imminent test position and were advised to wait for the tester to guide them into the position. Participants were encouraged to move at a uniform slow pace when placing themselves into a different position. Once in the critical position, they were instructed to start with mental alerting if this was applicable for a given test set. Each test position was maintained and for at least 30s, during which eye movements were recorded. During testing eye movements were being carefully observed on the computer screen and whenever persistent PN was observed, the position was maintained for at least 60 s or longer to examine whether the PN had any tendency to fatigue. Furthermore, whenever PN was detected, video-recording was also obtained to verify the character of the PN at a later point.

2.8 Data management

Since PN is by definition a type of nystagmus occurring as a result of the head (or the head and body) being moved from one position to another and lasting as long as the critical position is maintained (Barin, 2006), only cases of persistent PN were included into data analysis in this study. Intermittent eye movements are more susceptible to subjective interpretation as they often occur due to technical issues, for example crosstalk (Barin, 2006). For this reason intermittent eye movements were not included in the data analysis. In order for nystagmus to be classified as PN, it had to occur as soon as the participant was placed into the test position and last as long as the participant remained in the critical position.

For each VNG trace, horizontal and vertical channels were carefully examined by the tester for the presence of PN. Related video-recordings served as an efficient tool for confirming the presence and direction of the PN. Where PN was found, the SPV for each beat was measured using the CHART VNG software. The peak SPV was then identified by finding three strongest beats next to each other and taking the average of their SPVs. In cases of oblique PN, which presented as ‘mixed’ nystagmus in both the horizontal and vertical channels, the peak SPV was measured for both channels and the peak SPV of the channel with greater PN magnitude then determined the peak SPV of the oblique PN (Figure 2.1).

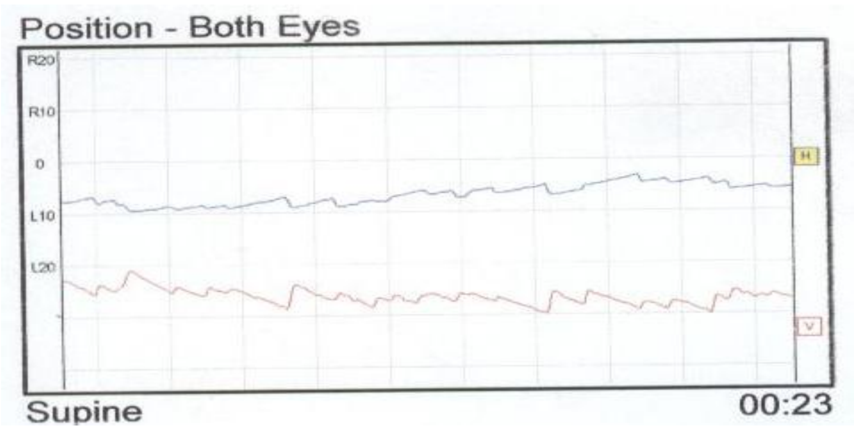

Figure 2.1: *Example of oblique PN recorded in one of the participants in SHS position.*

Next, all gathered data were plotted into the Microsoft Office Excel 2007 program. For each of the 44 tested positions (four sets of eleven positions) presence of PN was recorded as 0= PN absent or 1= PN present. Where PN was found to be present, the direction of the PN was recorded together with the average peak SPV (Appendix D).

CHAPTER 3 - RESULTS

3.0 Data analysis

The data sets were analysed using the Microsoft Office Excel 2007 program and the SPSS Statistics software version 17.0. A total of 22 participants were tested in 11 head and body positions in four individual test sets, producing 968 individual recordings. However, data of four participants had to be removed from the total data set due to poor quality of their recordings. Therefore, results of only eighteen participants (792 individual recordings) were included in the data analysis.

3.1 Prevalence of positional nystagmus- overview

Prevalence of PN was determined as presence of persistent PN within any one given position within any one given test set, irrespective of the direction and magnitude of the PN. In total, there were 123 valid cases of persistent PN across the 792 individual recordings (15.5%). Out of the 18 participants, 66.7% (n=12) demonstrated persistent PN in at least one test position in at least one of the four test sets. As the study consisted of four separate test sets, each including 11 test positions, a total of 44 data entries were obtained for each participant. In order to provide relevant data analysis, the PN prevalence was first reviewed in terms of overall prevalence across the entire study (that is the prevalence of the PN across all 44 test positions) and next across the 18 participants.

3.1.1 Prevalence of positional nystagmus across the entire study

Prevalence of PN across the entire study was examined using the Excel program. First, all valid cases of PN were counted across all four test sets for each head and body position and then expressed as a percentage of the total PN prevalence. Out of the total 123 valid cases of PN, the highest rate of PN occurred in the SHS position (16.3 %, n=20), being followed by the SHR (11.4 %, n=14) and the BRS (10.6 %, n=13) positions. The lowest prevalence on the overall was found in the HR position (5.69%, n=7). The remaining positions provided similar rates of PN (Figure 3.0).

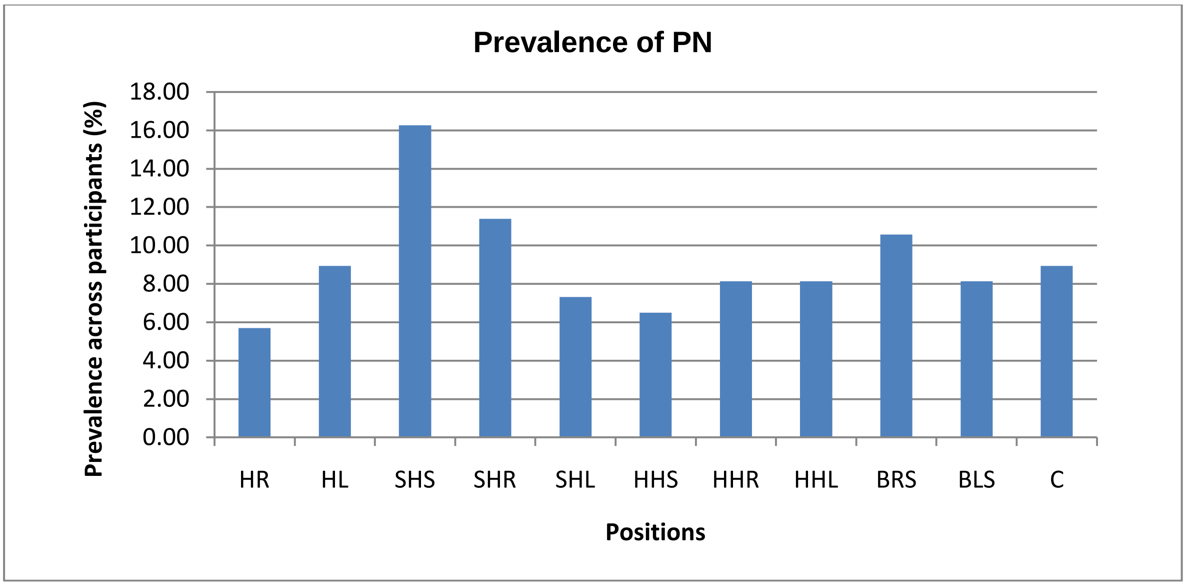

Figure 3.0: *Prevalence of PN in individual positions across all four test sets as a percentage of total prevalence.*

In terms of the individual test sets, the highest rate of PN occurred in the first test set with mental alerting (A1) for majority of the head and body positions apart from the SHR, SHL, and HHR positions (Figure 3.1). No consistent trend can be seen for other test sets.

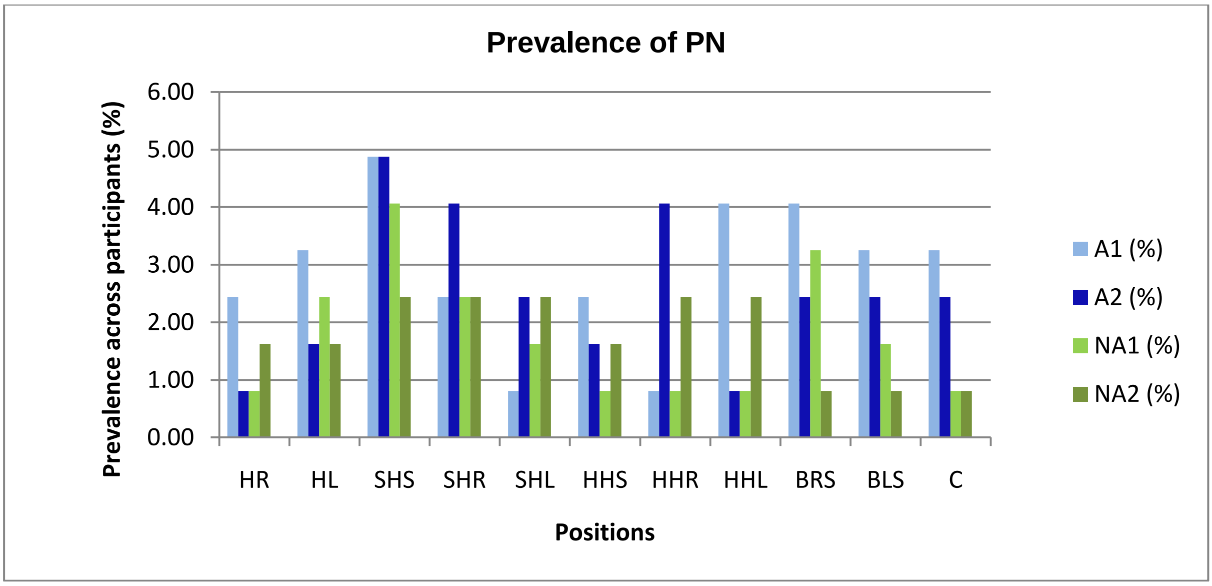

Figure 3.1: *Prevalence of PN in individual positions for the separate test sets as a percentage of the total PN prevalence. A1=mental alerting run 1, A2= mental alerting run 2, NA1= no mental alerting run 1, NA2= no mental alerting run 2.*

3.1.2 Prevalence of positional nystagmus across participants

Out of the 18 tested participants, 12 participants (66.7%) displayed persistent PN in at least one test position in at least one of the four test sets. Seventy five percent of these (n=9) had PN in both conditions with mental alerting and with no mental alerting, 16.6 % (n=2) had PN only in a condition with mental alerting, and 8.3% (n=1) participants had PN only in a condition with no mental alerting (Figure 3.2).

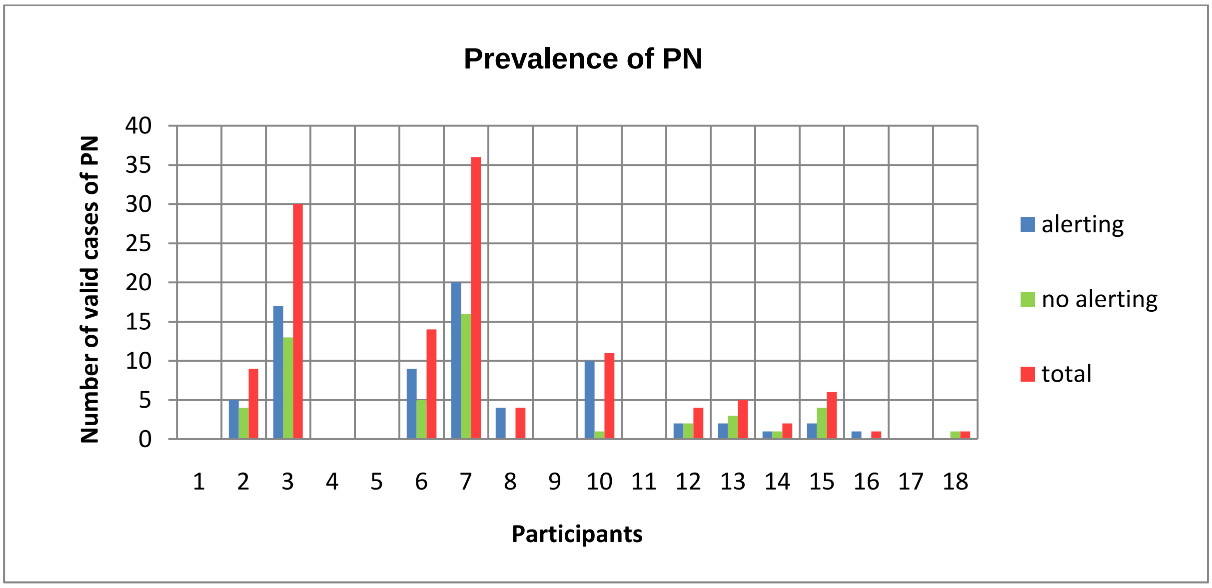

Figure 3.2: *Prevalence of PN for individual participants in conditions with mental alerting and with no mental alerting.*

Furthermore, the number of positions with PN across participants was examined for each of the four test sets. Table 3.0 shows that majority of participants had PN in fewer than five test positions; however, four participants (22.2%) had persistent PN in five or more test position of the 11 test positions (highlighted in red colour), out of whom one had PN in all 11 positions in the first test session with mental alerting.

Table 3.0: *Number of positions with PN for individual participants in individual test sets.*

Participant's number	A1	A2	NA1	NA2
1	0	0	0	0
2	2	3	2	2
3	9	8	7	6
4	0	0	0	0
5	0	0	0	0
6	5	4	1	4
7	11	9	8	8
8	2	2	0	0
9	0	0	0	0
0	5	5	1	0
11	0	0	0	0
12	1	1	2	0
13	1	1	2	1
14	0	1	0	1
15	2	0	3	1
16	1	0	0	0
17	0	0	0	0
18	0	0	0	1

3.2 Type of positional nystagmus

3.2.1 Prevalence of different types of positional nystagmus across the entire study

Within the present study, three main types of PN were observed. These were horizontal, vertical, and oblique. No cases of torsional PN were seen. Within the three main categories, seven subcategories of PN were determined. These were horizontal right-beating (HRB), horizontal left-beating (HLB), vertical up-beating (VUB), vertical down-beating (VDB), oblique up and right-beating (OURB), oblique up and left-beating (OULB), and oblique down and left beating (ODLB) PN. There were no cases of direction-changing PN for a particular type of PN (horizontal, vertical, or oblique) in any of the participants. No participant had PN with fixation.

Prevalence of PN in individual test positions across all four test sets was examined using Excel software. First, all valid cases of a particular type of PN were counted across all test sets for each head and body position and then expressed as a percentage of the total PN prevalence. Prevalence of the different types of PN is graphically illustrated in Figures 3.3, which shows that vertical up-beating (VUB) PN was the most common type of PN, accounting for 45.6% (n=57) of all valid cases of PN. The least common type of PN was vertical down-beating, accounting for only one case of PN. Figure 3.4 provides more detailed overview of prevalence of different types of PN, taking the head and body position into consideration.

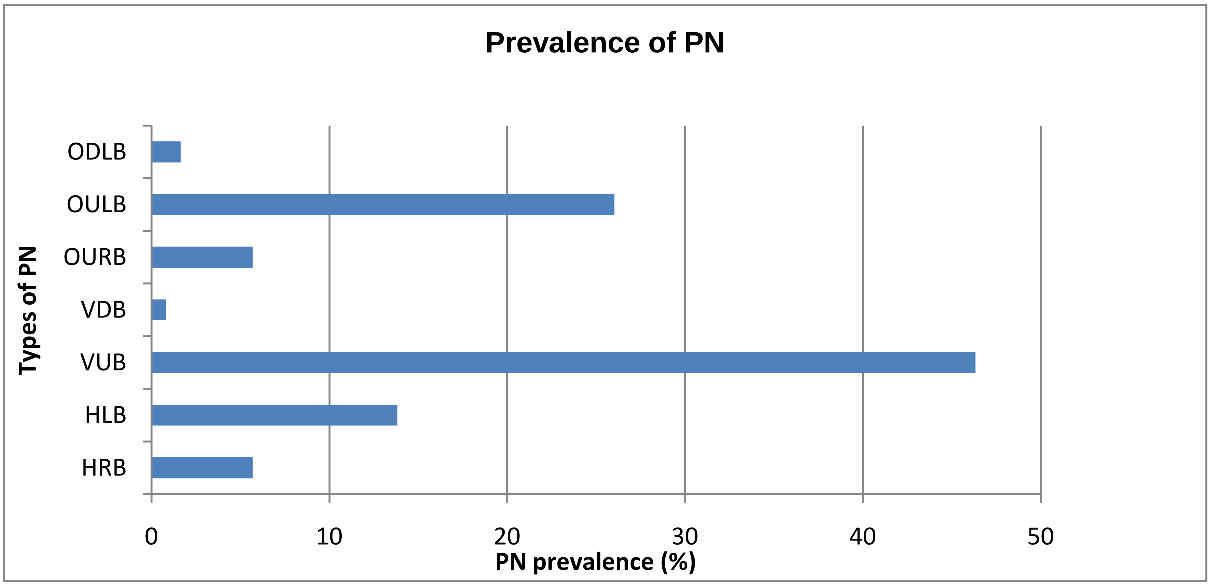

Figure 3.3: *Overall prevalence of different types of PN across the entire study. HRB= horizontal right-beating, HLB= horizontal left-beating, VUB= vertical up-beating, VDB= vertical down-beating, OURB= oblique up and right-beating OULB= oblique up and left-beating, ODLB= oblique down and left beating.*

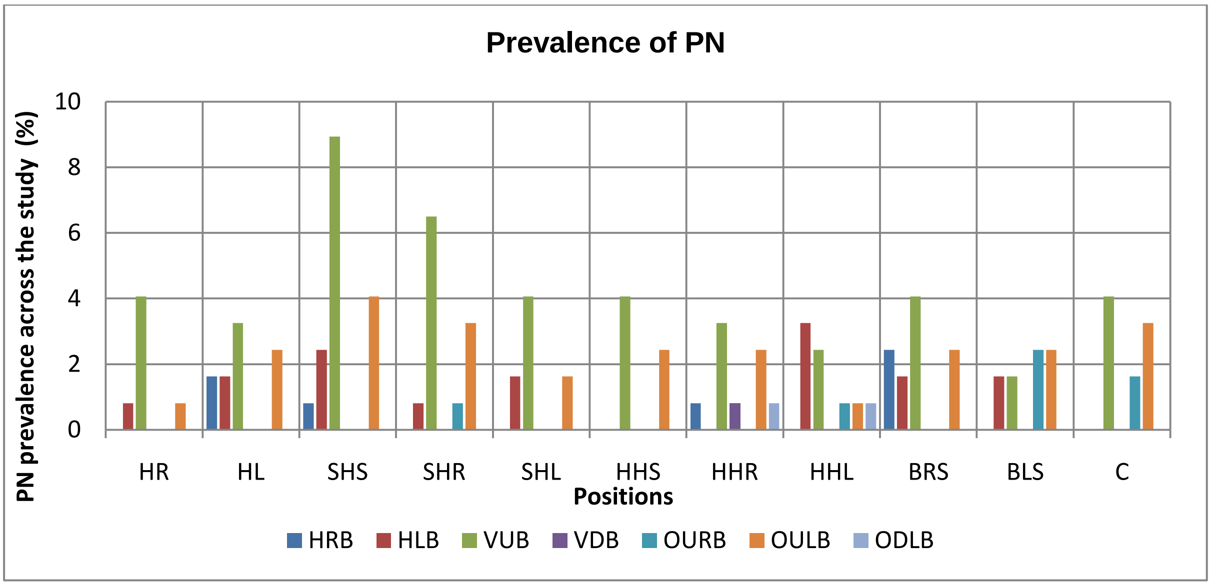

Figure 3.4: *Prevalence of different types of PN in individual test positions. HRB= horizontal right-beating, HLB= horizontal left-beating, VUB= vertical up-beating, VDB= vertical down-beating, OURB= oblique up and right-beating OULB= oblique up and left-beating, ODLB= oblique down and left beating.*

3.2.2 Prevalence of different types of positional nystagmus across participants

Of the 12 participant who had PN in at least one test position and at least one test set, nine participants (75%) had horizontal PN, eight participants (66.7%) vertical PN, and five participants (41.7%) oblique PN. Horizontal left-beating PN and VUB PN were the most common cases of PN (58.3%, n=7) (Table 3.1). Figure 3.5 illustrates presence of the three main types of PN in individual participants. Five participants (41.7%) manifested only one type of PN, four participants (33.3%) two types of PN, and three participants (25%) three types of PN during static position testing.

***Table 3.1**: Prevalence of different types of PN across the 12 participants with at least one valid case of PN.*

Type of PN	Number of participants with PN	Prevalence (%)
Horizontal right-beating	2	16.7%
Horizontal left-beating	7	58.3%
Vertical up-beating	7	58.3%
Vertical down-beating	1	8.3%
Oblique up and right-beating	1	8.3%
Oblique up and left-beating	3	25%
Oblique down and right-beating	0	0%
Oblique down and left-beating	1	8.3%

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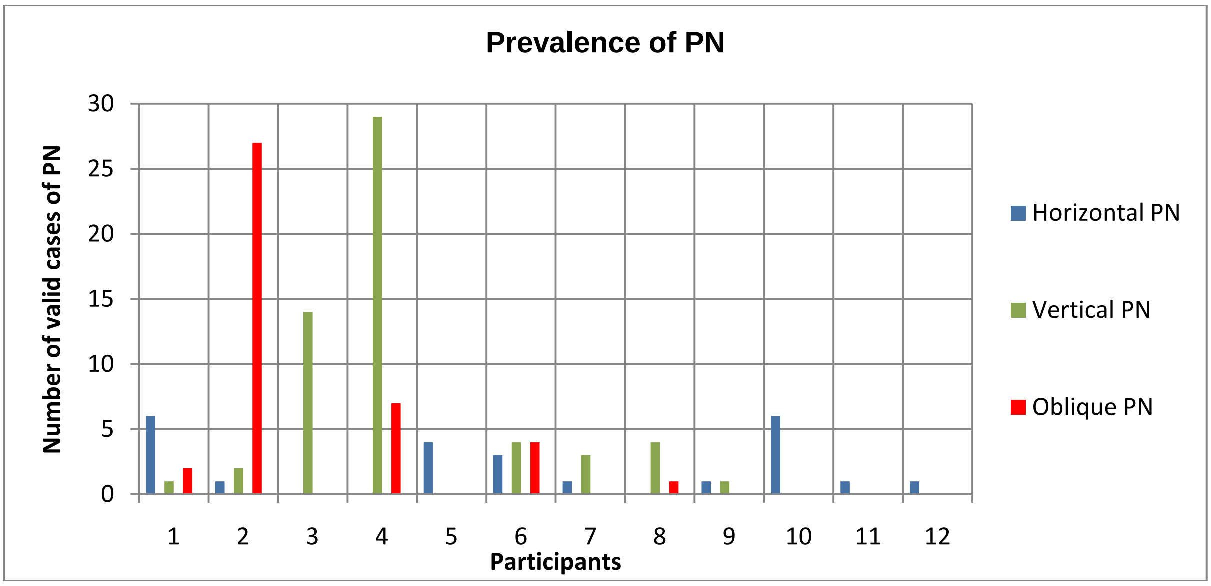

Figure 3.5: *Prevalence of different types of PN for those 12 participants who had at least one valid case of PN.*

3.2.3 Peak slow phase velocities of different types of positional nystagmus

The mean peak SPVs of different types of PN are shown in Figure 3.6. The mean peak SPV for vertical PN was 4.82°/s (SD= 2.01), with the upper bound of the 95% CI being equal to 5.3°/s. The mean peak SPV for horizontal PN was 2.78 °/s (SD= 1.05), with the upper bound of the 95% CI being equal to 3.2°/s. The mean peak SPV for oblique PN was 6.33°/s (SD= 2.61), with the upper bound of the 95% CI being equal to 7.2°/s. It is apparent from Figure 3.6 that oblique PN had the greatest SPV magnitude compared to the other types.

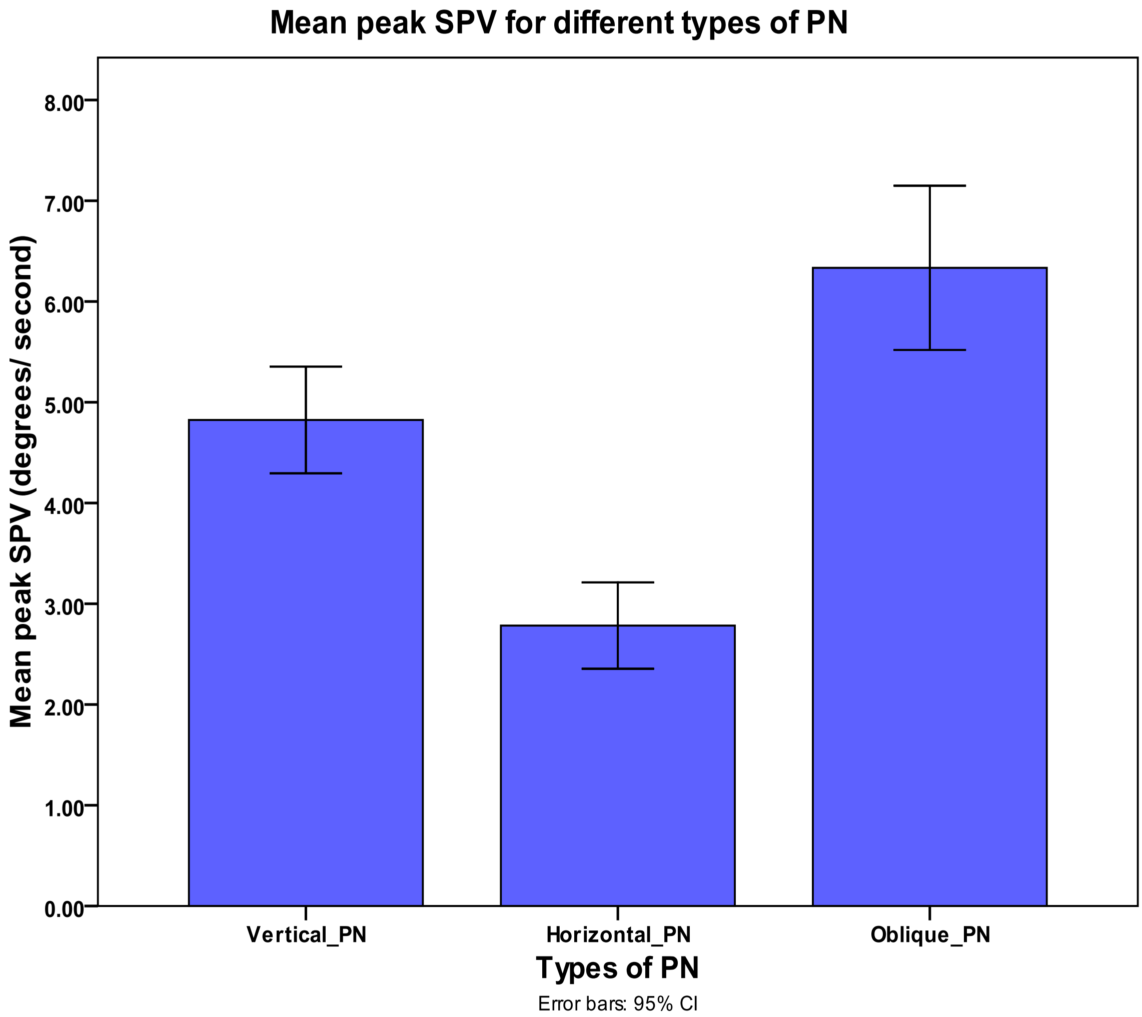

Figure 3.6: *Error bars represent the mean peak SPVS with 95% CI across participants for the three main types of PN.*

3.3 Effects of mental alerting

3.3.1 Prevalence of positional nystagmus

Due to the nominal nature of PN prevalence, the data were first analysed using Excel software and represented graphically. First, all valid cases of PN were counted across all four test sets for each head and body position and then expressed as a percentage of the total PN prevalence. Figure 3.7 shows that with an exception of the SHL position, the prevalence of PN was higher in the test sets with mental alerting than in those without.

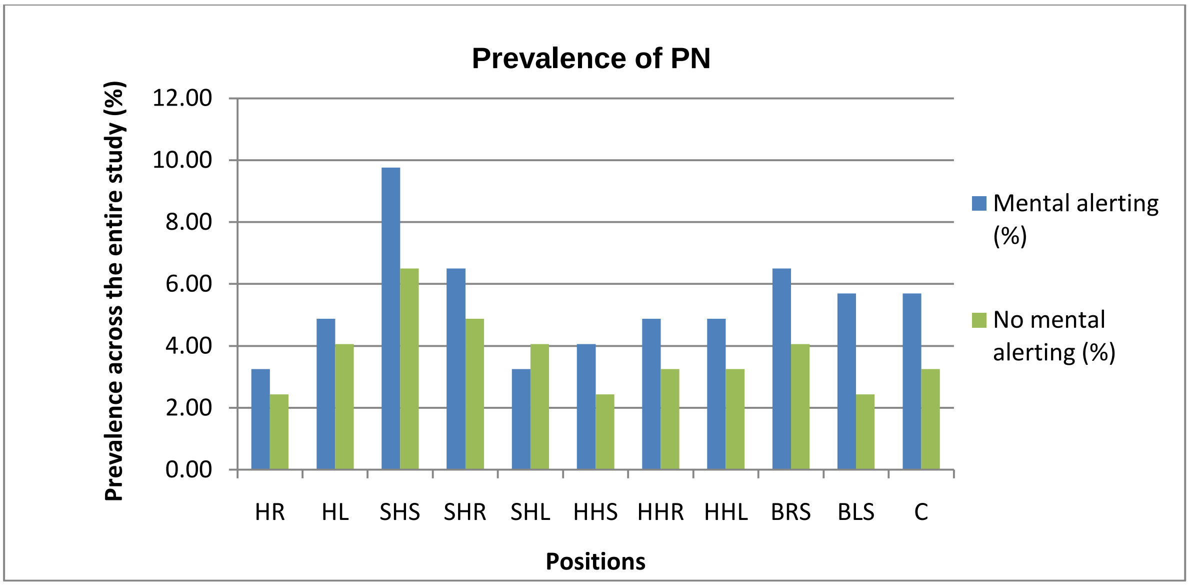

Figure 3.7: *Prevalence of PN in individual positions for conditions with mental alerting and with no mental alerting as a percentage of the total PN prevalence.*

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In order to test statistical significance of the effects of mental alerting across participants, all valid cases of PN were counted across the two test sets with mental alerting and the two test sets without mental alerting separately for each participant. These sums were converted into percentages of the total number of all valid cases of PN across the entire study. In this way, two scores for each participant were obtained; one for the combined test sets with mental alerting and another for the combined test set without mental alerting.

Shapiro-Wilk test revealed that the data were grossly abnormally distributed (p= 0.000). Non-parametric Wilcoxon signed-rank test showed a significant effect of mental alerting (z= -1.81, p< 0.05, r= -0.30) on the PN prevalence.

3.3.2 Peak slow phase velocity of positional nystagmus

In a second analysis of the results, peak SPVs for test sets with mental alerting and test sets without mental alerting were analysed for those 12 participants who demonstrated PN in at least one test positions in at least one test set. The input data for the SPSS analysis was obtained by averaging the mean peak SPVs across all 11 test positions for each participant for test sets with mental alerting and test sets without mental alerting.

Shapiro-Wilk test revealed that the data were abnormally distributed. Non-parametric Wilcoxon signed-rank test showed that there was no significant effect of mental alerting on the magnitude of the peak SPVs ($z = -0.549$, $p > 0.05$).

Figure 3.8 shows the inter-quartile ranges and medians for the two conditions. From this figure it is apparent that mental alerting had no significant effect on the mean peak SPV. Closer inspection of the results revealed that participant number seven was an outlier for the test condition with mental alerting, displaying significantly higher mean peak SPV than the rest of the participants. The raw data showed that this participant had PN in 20 positions out of the 22 where mental alerting was used. The mean peak SPVs for this participant ranged from 2.4 to 13.3 °/s. Participant number sixteen was also an outlier for the test condition with mental alerting. This was because this participant had one valid case of PN in the condition without mental alerting, but none in the condition with mental alerting, hence producing a null result for the mean peak SPV.

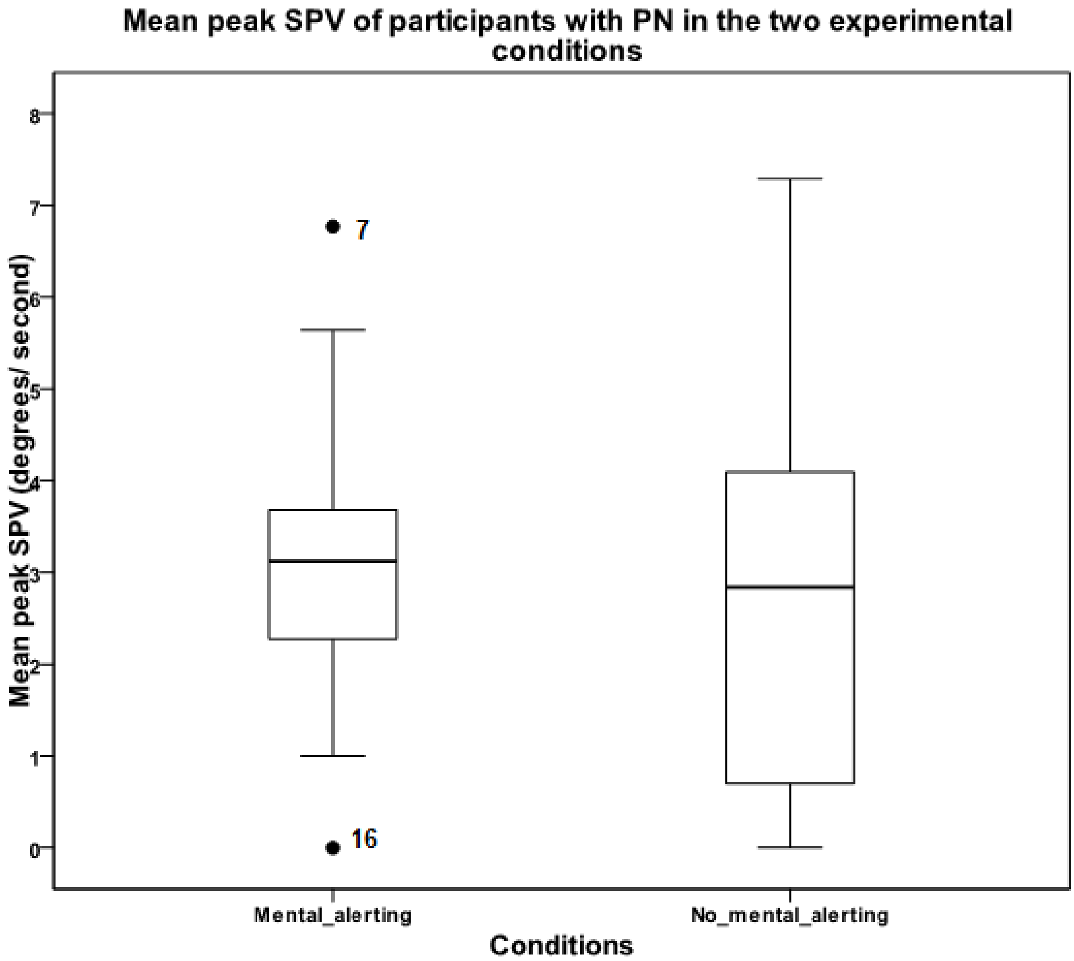

Figure 3.8: *Box plot representing the medians of mean peak SPVs in the two experimental conditions.*

3.4 Within session repeatability of positional nystagmus

3.4.1 Within session repeatability of prevalence of positional nystagmus

Within session repeatability of PN prevalence was examined by analysis of data derived from the paired test sessions, that is test sessions with mental alerting and test sessions without mental alerting. The prevalence repeatability was examined by directly comparing the prevalence across the two related test sessions. Where PN occurred in an individual test position in both related test sets, this was classified as a repeatable response. Where PN occurred in an individual position only in one of the two related test sets, this was classified as non-repeatable response. Each repeatable case of PN across the two related test sets scored value 1 and each non-repeatable case of PN also scored 1. The total scores were then converted into a percentage of the total PN prevalence across the entire study and represented graphically, using Excel software.

Figure 3.9 shows the results for the paired test sessions averaged across the 11 test positions. The figure demonstrates that the cases of PN elicited in sessions with mental alerting were almost equally repeatable (21.94%) as not repeatable (21.95%). In contrast, cases of PN elicited in sessions without mental alerting were significantly more non-repeatable (20.33%) than repeatable (9.74%).

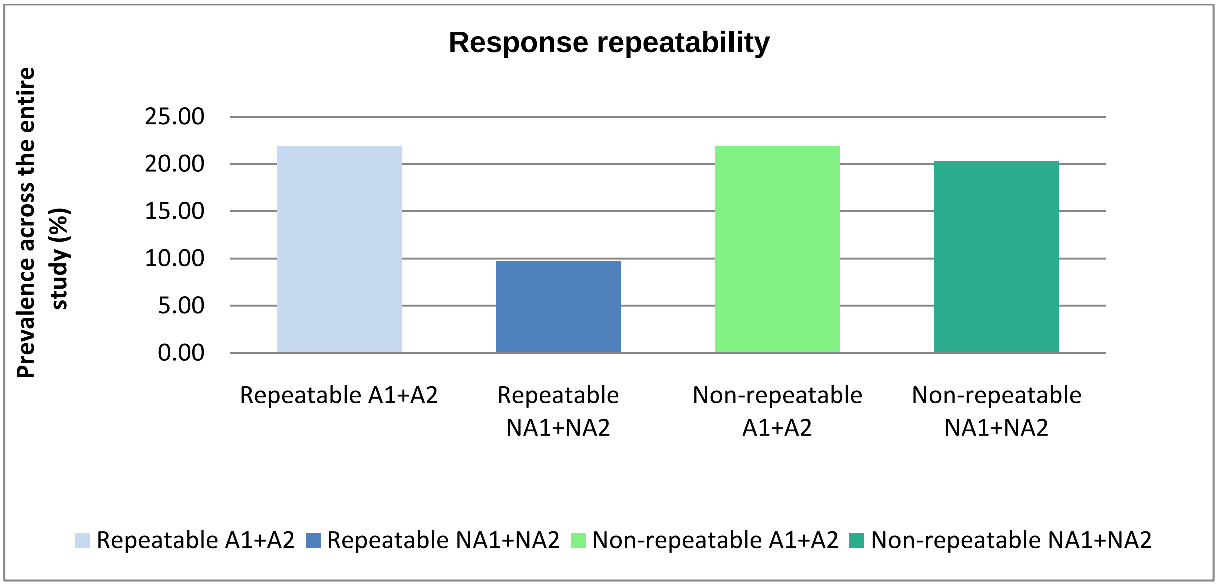

Figure 3.9: *Repeatability of PN for within session test averaged across the 11 test positions.*

Figure 3.10 then demonstrates repeatability of the paired session in each of the 11 head and body positions. It remains apparent that repeatability was generally higher for the test sets with mental alerting than those without mental alerting. The SHS provoked the highest rates of repeatable PN in the condition with mental alerting; however, it also provoked the highest rate of non-repeatable PN in the condition without mental alerting.

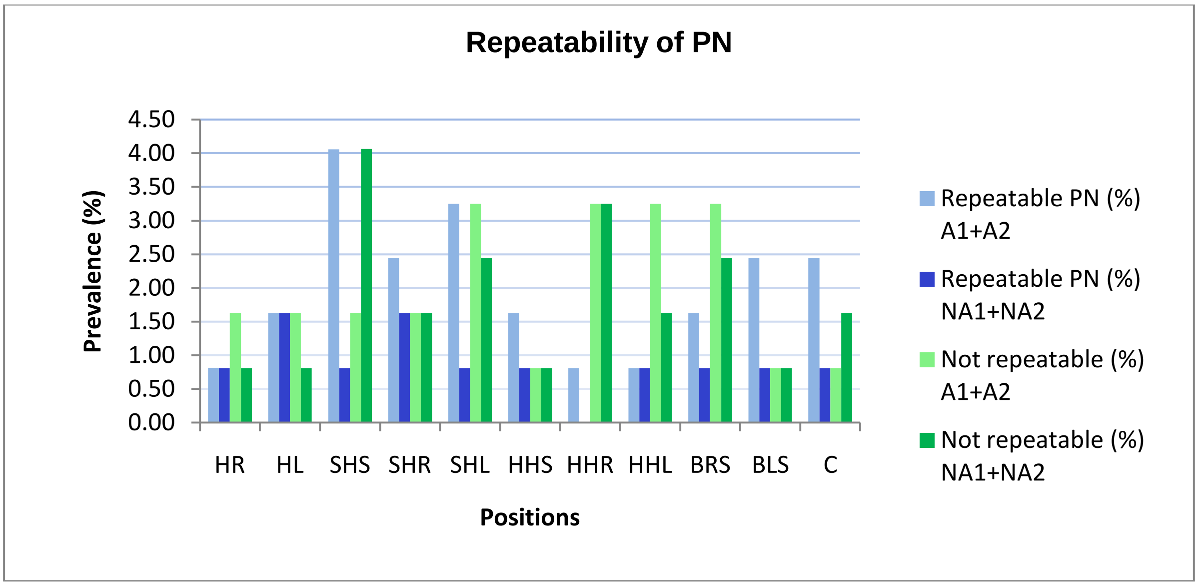

Figure 3.10: *Repeatability of PN within session tests for individual test positions*

3.4.2 Within session repeatability of peak slow phase velocity

Peak SPV magnitudes were compared for the paired test sessions with mental alerting and for the paired test sessions without mental alerting. The Shapiro-Wilk test revealed that the data were grossly abnormally distributed ($p< 0.05$). Non-parametric Wilcoxon signed-rank test using the Bonferroni correction showed that there was no significant difference between the peak SPV magnitudes within the paired test with mental alerting for any of the 11 body positions ($p>0.0045$). Similarly, there was no significant difference between the peak SPV magnitudes within the paired test without mental alerting for any of the 11 body positions ($p>0.0045$) (Table 3.2).

Table 3.2: *Wilcoxon signed rank test for peak SPV measurements for paired session comparison*

	Wilcoxon Signed Rank Test for test sessions with mental alerting		**Wilcoxon Signed Rank Test for test sessions without mental alerting**	
	p	Z	p	Z
HR	>0.0045	-1.604	>0.0045	-1.069
HL	>0.0045	-1.095	>0.0045	-1.604
SHS	>0.0045	-0.676	>0.0045	-1.183
SHR	>0.0045	-1.625	>0.0045	-0.730
SHL	>0.0045	-0.365	>0.0045	-0.730
HHS	>0.0045	-1.069	>0.0045	-1.342
HHR	>0.0045	-2.023	>0.0045	-1.095
HHL	>0.0045	-1.753	>0.0045	-1.604
BRS	>0.0045	-1.261	>0.0045	-1.826
BLS	>0.0045	-0.730	>0.0045	-0.447
C	>0.0045	0.000	>0.0045	-1.604

3.5 Effects of head and body positions

3.5.1 Effects of head and body position on prevalence of positional nystagmus

The effects of head and body position on the PN prevalence were examined by counting cases of PN in individual head and body position across participants and expressing them as a percentage of the total PN prevalence. Figure 3.11 shows that the highest rate of PN was generated by the SHS position 16.3% (n=20), being followed by SHR 11.4% (n=14) and BR positions 10.6% (n=13). The lowest rate of PN was generated by the HR position 5.7% (n=7). The remaining positions generated similar rates of PN, thus all test positions had the ability to provoke some cases of PN.

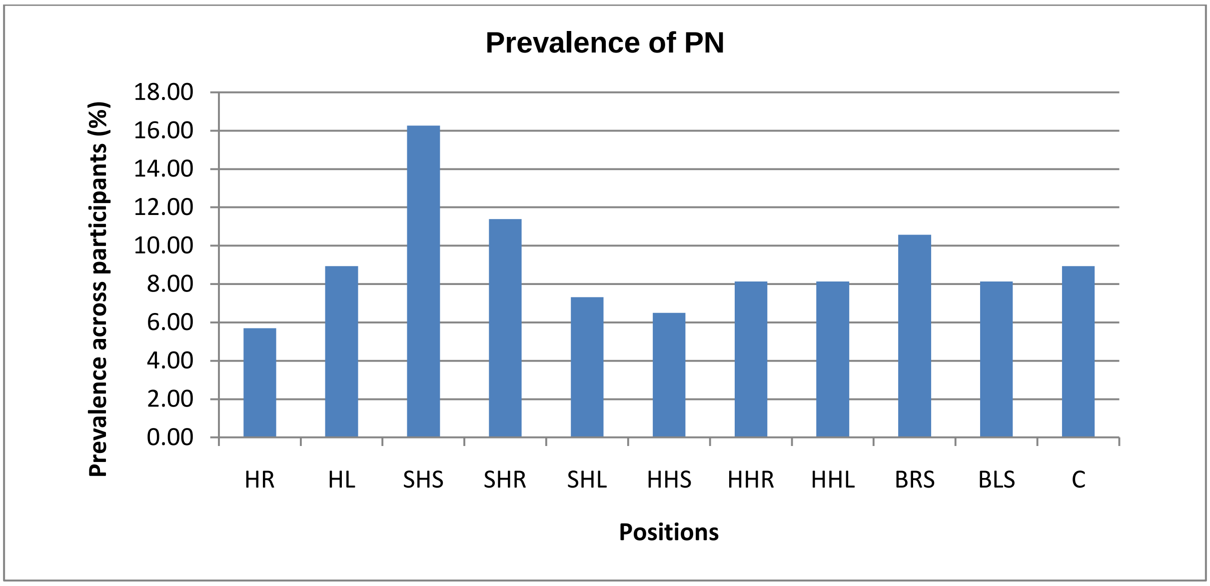

Figure 3.11: *Prevalence of PN in individual positions across all four test sets as a percentage of total prevalence.*

3.5.2 Effects of head and body position on peak slow phase velocity

The effects of head and body positions on the peak SPV was examined by obtaining mean peak SPVs for a given position across all four test sets and representing the data in a form of error bars. It is apparent from figure 3.12 that the largest magnitude SPV occurred in the SHR position (mean= 6.71°/s, SD= 2.17), being followed by the HHS (mean= 5.98°/s, SD= 2.05) and the HHR (mean= 5.81°/s, SD= 2.08) positions. The smallest magnitude SPV occurred in the HL (mean= 3.71°/s, SD= 1.47) and the BRS (mean= 3.84°/s, SD= 1.7) positions.

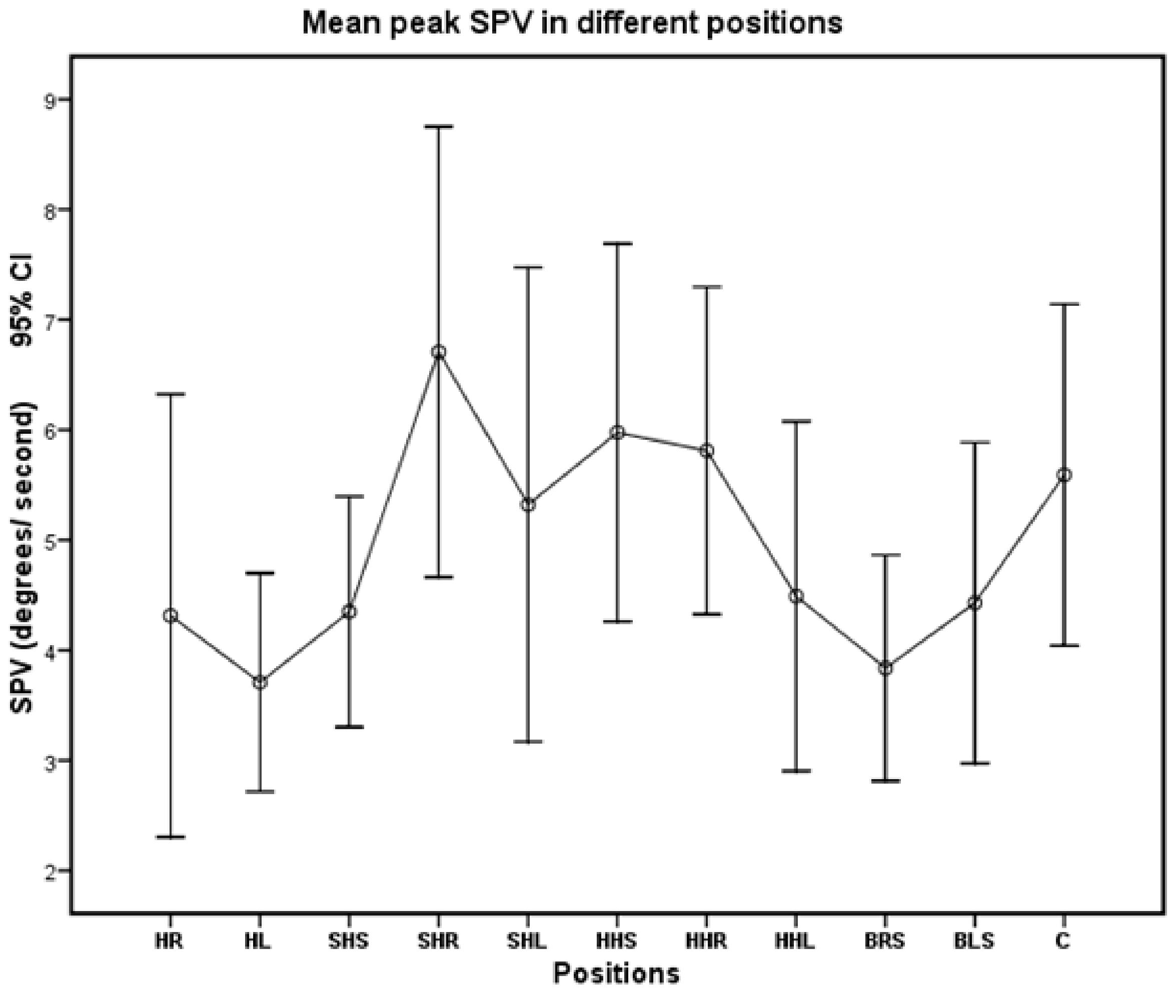

Figure 3.12: *Error bars represent the mean peak SPV with 95% CI for the 11 test positions.*

CHAPTER 4- DISCUSSION

4.0 Overview of findings

The present study investigated prevalence of PN during static positional testing in 18 normal healthy participants using VNG. Each participant underwent four sets of static positional testing, each involving 11 identical test positions. Two sets were conducted with mental alerting and two sets without mental alerting. The results showed that 66.7% (n=12) of the participants developed persistent PN in at least one test position in at least one of the four test sets. Three main types of PN were found in this study: vertical, horizontal, and oblique. The most common type of PN across the entire study was vertical up-beating (VUB) PN (45.6%, n=57). However, the most common type of PN across individual participants was horizontal PN (75%, n=9), being followed by vertical PN (66.7%, n=8). Oblique PN had the greatest mean peak SPV. The greatest SPV magnitude occurred in the SHR position (mean= 6.71°/s, SD= 2.17), being followed by the HHS (mean= 5.98°/s, SD= 2.05) and HHR (mean= 5.81°/s, SD= 2.08) positions. The results further suggested that mental alerting had significant effect on prevalence of PN, but it did not increase the magnitude of the SPV. The PN was only modestly repeatable within the paired mental alerting and non-mental alerting test sets, and the repeatability was generally greater for the test sets with mental alerting. There were no significant differences between the SPV magnitudes within the paired test sets, suggesting good within- session repeatability of the SPV magnitudes. Generally, the SHS and SHR provoked the highest rates of PN (16.3 % and 11.4 %, respectively); however, there was no one position that would not provoke PN in at least one participant and at least one test set.

4.1 Prevalence

There has been a wide range of prevalence of PN reported by earlier studies examining prevalence of PN in normal healthy participants using VNG prior to this study (Table 4.0). However, designs of those studies varied greatly, making a direct comparison difficult. The present study found 66.7% (n=12) to have persistent PN in at least one position in at least one of the four test sessions. This finding fits well into the available literature, supporting the concept that PN does occur frequently in normal healthy population.

Table 4.0: *Reported prevalence of PN across studies.*

Study	**Number of participants**	**Number of positions**	**Criterion for presence of PN**	**Overall prevalence of PN**
Present study	18	44 (4x11)	Persistent PN	66.7%
Copperwheat (2005)	38	44 (4x11)	≥3 consecutive beats of PN	100%
Barin & Roth (unpublished, as cited in Barin, 2006)	40	6	Unclear	97%
Levo et al. (2004)	20	3	≥5 consecutive beats of PN	55%
Sunami et al. (2004)	89	8	Unclear	73%
Schneider (2000)	25	9	≥3 consecutive beats of PN	48%
Bisdorff et al. (2000)	18	5	Unclear	100%
Geisler et al. (2000)	29	11	≥5 consecutive beats of PN	55%

The most similar experimental design to the present study was found in a study by Copperwheat (2005). The study by Copperwheat (2005) also consisted of four sets of testing and used 11 identical test positions. The researcher found that all 40 participants (100%) had PN in at least one position in at least one of the four test sessions. However, this study used different criterion for determining presence of PN. Copperwheat (2005) considered PN to be present if at least three consecutive beats of nystagmus were seen within 30 seconds of the recorded trace. This criterion has been discussed earlier on and its susceptibility to subjective assessment has been pointed out. Review of data from the study by Copperwheat (2005) showed that sporadic (intermittent) PN was predominant, and that if only persistent PN had been included into the data analysis, the PN prevalence would have decreased to 35%. Similarly, a study by Barin and Roth (unpublished, as cited in Barin, 2006 and Barin, 2008) also found high prevalence of PN (97%) among 40 healthy normal participants**.** This is surprisingly high prevalence, especially seeing that participants were tested only in six positions. While Barin (2006) argues that there is no known pathology that generates sporadic PN, the author of the unpublished study does not specify whether only cases of persistent PN were included in the data analysis. Thus this could partly explain the high prevalence of PN.

4.2 Type of positional nystagmus

4.2.1 Prevalence of different types of positional nystagmus

Only few other studies looked at prevalence of different types of PN. This study found vertical up-beating (VUB) PN to be the most common type of PN across the entire study, accounting for 43.3% (n=57) of all valid cases of PN. Interestingly, the second most common type of PN was oblique up- and left-beating (OULB) PN, accounting for 26% (n= 32) of all valid cases of PN. Horizontal left-beating (HLB) and horizontal right-beating (HRB) accounted for only 5.69% (n= 7) and 13.8% (n= 17) of all cases of PN, respectively. In comparison, Copperwheat (2005) found a clear predominance of HLB PN (57.7%) across the entire study, with VUB being the second most common type of PN (16.8%). Cases of oblique PN represented only 3.8% of all valid cases of PN.

On reviewing the raw data of the present study it was noted that participant number three and participant number seven were significant contributors to the high prevalence of VUB and OULB PN by having persistent and highly-repeatable PN across all four tests sets. Participant number three displayed 30 valid cases of PN in the 44 test positions, most of which were cases of OULB, and participant number seven displayed 36 valid cases of PN in the 44 test positions, most of which were cases of VUB. None of those participants had any history of balance problems and none of them experienced any dizziness during the testing. It was stipulated that their data could skew the results of the analysis. In order to assess the effect of this on the whole data set, results of those participants were experimentally removed. While removal of the data did not affect predominance of the VUB PN; prevalence of VUB PN remained as high as 45.6%, overall prevalence of OULB was significantly decreased to 8.8%. As a result, HLB PN became the second most prevalent case of PN (28.1%), which is a finding more in line with results of the study by Copperwheat (2005**).**

In terms of prevalence of different types of PN across individual participants, this study found that of the 12 participants, who had PN in at least one test position and at least one test set, nine participants (75%) had horizontal PN, eight participants (66.7%) vertical PN, and five participants (41.7%) oblique PN. The most common types of PN across participants were HLB and VUB PN, each being present in 58.3% of the participants (n=7). The finding of the high prevalence of VUB is consistent with the study by Barin and Roth (unpublished, as cited in Barin, 2006 and Brain, 2008), who also found VUB PN to be frequently present in normal healthy population. In fact, in their study VUB PN was the most common type of nystagmus (87.5%).

This is the only study that recorded high prevalence of persistent oblique PN amongst healthy population. Sunami et al. (2004) reported cases of 'mixed horizontal and vertical' PN in their study, which were detected in 18.5% (n=12) of the participants with PN, but the study was lacking in methodology and therefore the results cannot be directly compared. Similarly, Copperwheat (2005) found oblique PN to be present in healthy normal participants (3.8%); however, the prevalence was derived from all four test sets and Copperwheat (2005) does not explain how many individuals contributed to this statistics. The high prevalence of oblique PN could be perhaps explained by the fact that four out of the five participants with oblique PN were young University students between ages of 22 and 24. It is possible that factors, such as lack of sleep or non-reported consumption of alcohol in less than 24 hours prior to the start of testing, could have contributed to high prevalence of oblique PN.

4.2.2 Mean peak slow phase velocity of different types of positional nystagmus

The mean peak SPVs were measured separately for the horizontal, vertical, and oblique PN. Oblique PN had the greatest SPV magnitude with the upper bound of the 95% CI equal to 7.2°/s, being followed by vertical PN (upper bound of the 95% CI= 5.3 °/s), and horizontal PN (upper bound of the 95% CI = 3.2°/s). To date, there are only two other studies reporting separate values of SPVs for different types of PN in conjunction with the use of VNG (Barin and Roth, unpublished, as cited in Barin, 2006; Levo et al., 2004).

The upper limit of the 95% CI for the mean peak SPV of horizontal PN found in this study is slightly lower compared to results of older studies using ENG (Coats, 1993; Mulch & Lewitzki, 1977 Barber & Wright, 1973). In fact, there was no case of horizontal PN in this study that would exceed the 6°/s threshold. The result is however consistent with findings of more recent studies using VNG. Barin (2008) revisited results of his unpublished study (Barin and Roth, cited in Barin, 2006) and reported the 95% CI for horizontal PN to be 4°/s. This is surprisingly close to the limit found in the present study. Similarly, in a study by Levo et al. (2004) the peak SPV of horizontal PN did not exceed 2.5°/s for any of the participants with PN. Overall, this suggests that the current upper limit for horizontal PN may be too high and should be lowered.

The upper limit of the 95% CI for the mean peak SPV of vertical PN found in this study is also close to the 95% CI upper limit reported by Barin (2008), who found this to be 7°/s. Levo et al. (2004) reported significantly lower magnitude of SVP for individual cases of vertical PN (≤2.5°/s); however, there were only four participants presenting with vertical PN.

This is the only study reporting high prevalence of oblique PN, with the PN also having the greatest mean peak SPV amongst the other types of PN. Since one of the participants presented with persistent highly-repeatable oblique PN in majority of the test positions, it was suspected that this participant’s data could have skewed the results. However, even after removal of that data, oblique PN continued to have the greatest average peak SPV (mean= 5.2°/s) across the three main types of PN. There are no other data in the literature against which this result could be compared, which again highlights the need for a robust normative study that could investigate this.

4.3 Effects of mental alerting

The original hypothesis regarding the effects of mental alerting on PN theorised that mental alerting would increase prevalence and magnitude of SPV of PN in the normal healthy population. The results of this study suggest that mental alerting increases prevalence of PN; however, it does not have statistically significant effect on magnitude of SPV. This is an interesting finding, as it would be expected that with an increase in PN prevalence an increase in the PN magnitude would occur as well. This could be partially explained by the fact that majority of the participants were young University students (55.6%), for whom the mental alerting task may not have been sufficiently difficult. As a result the nystagmus suppression mechanism may not have been sufficiently inhibited. Furthermore, it is likely that different individuals had different abilities of nystagmus suppression, which may have generated more variation in the results. It is also worth noting that the magnitude of the observed effect of mental alerting on prevalence of PN was rather small (r=-0.30).

Two other studies looked at the effects of mental alerting on prevalence and magnitude of PN (McGovern & Fitzgerald, 2008; Humphriss et al., 2005). While Humphriss et al. (2005) reported no effects of mental alerting; McGovern and Fitzgerald (2008) found mental alerting to have a significant effect on both, the presence and magnitude of SN and PN. However, both studies investigated on patients with known balance problem and confirmed presence of PN and SN. For this reason the results of their studies may not be directly comparable to those in the present study. Furthermore, Humphriss et al. (2005) used only a small sample (n=10) of patients, which decreases power of the study. In contrast, McGovern and Fitzgerald (2008), who investigated on a larger sample of 30 patients, used only two positions for the static positional test, the BRS and BLS positions. The results therefore may not represent the overall effects of mental alerting across all positions. In order to test this notion and compare results of the present study more directly to the study by McGovern and Fitzgerald (2008), a small statistical experiment was carried out. The SPVs of PN elicited in the BRS and BLS positions in the first test set with mental alerting were compared to those elicited in the same test positions in the first test set without mental alerting using Wilcoxon Signed Rank Test. The results showed that there were no significant differences between the test sets with mental alerting and with no mental alerting ($p > 0.025$).

4.4 Response repeatability

Prior to the start of testing it was hypothesised that there would be a weak test-retest repeatability of PN in the normal healthy population. The results of this study confirm this hypothesis. The present study found that cases of PN elicited in test sessions with mental alerting were only modestly repeatable and cases of PN elicited in test sessions without mental alerting were only weakly repeatable. Even though the test sessions with mental alerting yielded relatively low PN repeatability, they were nevertheless more successful at generating repeatable PN than sessions without mental alerting (21.95% versus 9.74%). This is potentially important clinical implication as a tester may wish to repeat measurement in a particular test position. Hence this finding provides another example of the benefit of mental alerting during static positional testing. Furthermore, this study found no significant differences between peak SPV magnitudes within the paired tests for any of the 11 body positions in conditions with mental alerting and with no mental alerting. This suggests that PN has a relatively stable magnitude on repetition of measurement for majority of normal healthy participants with PN. A similar finding to the above was reported by Copperwheat (2005), who also recorded only modest within-session response repeatability, but found correlation between peak SPV magnitudes within related test sessions for all positions apart from the SHL and BRS positions.

4.5 Effects of head and body position

4.5.1 Effects of head and body position on prevalence of positional nystagmus

The original hypothesis regarding the effects of head and body position on prevalence of PN suggested that there would be no significant difference found in prevalence of PN in different test positions. The results of this study confirm this null hypothesis. While the SHS position generated the highest prevalence of PN across the four test sessions (16.3%, n=20), some other test positions generated similarly high rates of PN. There was no position that would not generate at least one case of PN across the four test sessions. In fact, the minimal provocation rate of PN per position was 5.69% (n=7).

Different studies investigating prevalence of PN in a normal healthy population using VNG found a wide range of results. Copperwheat (2005) found that left-sided positions (namely, the SHL, HHL, and BLS positions) provoked consistently the highest rates of PN across all four test sessions. This trend was not observed in this study. Schneider observed PN in all nine test positions, with the HHL provoking only modestly higher rate of PN than the other positions. Geisler et al. (2000) observed the highest rates of PN in the HHR and HHL positions and in the ‘right and left forward Dix-Hallpike’ positions. In a study by Sunami et al. (2004) PN was most frequently recognised in the BRS and BLS positions in the eight tested positions (46.1% and 42.7%, respectively); however, the raw data shows that the increased prevalence of PN was not greatly different from majority of the other positions. Similarly, Aoki et al. (2008) found twice as high rates of PN in the BRS and BLS positions compared to the SHR and SHL positions, suggesting that the ‘head-and-body manoeuvre’ was more efficient at eliciting PN than the ‘head-only manoeuvre’. This finding was not replicated in this study. While in this experiment the BLS position provoked higher rates of PN than the SHL position (8.1% versus 7.3%, respectively), it was an insignificant difference. The opposite applied to the BRS and SHR positions, where the SHR position provoked marginally higher rates of PN than the BRS position (11.4% versus 10.6%, respectively). Is worth noting that Aoki et al. (2008) used ENG in their experiment, which does not allow accurate recording of vertical PN, and this can explain why this finding was not replicated in this study.

The discussion above illustrates that there is no one test position that would generate consistently the highest rates of PN across different studies. The results of the studies suggest that every one test position can generate some PN and the differences in the prevalence of PN across studies are likely due to differences in their methodologies and expected variations amongst the population.

4.5.2 Effects of head and body position on peak slow phase velocity

There was no hypothesis stated with regards to the effects of head and position on peak SPV. This was dues to the fact that previous studies placed more emphasis on prevalence of PN than SPV and limited amount of data were available for comparison. The only study reporting mean peak SPVs in different positions is a study by Copperwheat (2005). Copperwheat (2005) also observed the smallest magnitude in the HL position (mean= 2°/s). Unlike the present study, which found the largest magnitude of SPV in the SHR position (mean= 6.71°/s), Copperwheat (2005) found the greatest mean peak SPV to occur in the HHS position (mean= 3.7°/s).

4.6 Criteria for pathological positional nystagmus

At the present no diagnostic criteria for pathological PN in conjunction with VNG exist. The criteria recommended by Shepard and Telian (1996) are based on ENG and may not be suitable for use with VNG. Recently, those criteria were revisited by Copperwheat (2005), who concluded that pathological PN should fulfil at least one of the four categories:

1. PN (intermittent or persistent) with SPV >6°/s.
2. Persistent PN with SPV <6°/s, which is present in at least five positions or more of the 8-11 positions.
3. Intermittent PN with SPV <6°/s, but present in all test positions.
4. Direction-changing PN within a given test position.

The present study accepted only cases of persistent PN into data analysis and therefore criterion number 3 is not relevant for discussion within this study. Furthermore, there were no cases of direction-changing PN within a given position amongst the normal healthy population in this study, suggesting that this criterion does not require any refinement.

Criterion number 1 states that any PN, intermittent or persistent, with SPV greater than 6°/s is clinically significant. If this criterion were applied to the studied population, the results of the study would indicate that 11.1% of the participants (n=2) had clinically significant PN. However, none of these participants had any history of otological problems or dizziness. The review of raw data revealed that both these participants had high prevalence of PN across different test positions and test sets. Both participants also had more than 50% of their PN cases exceeding the 6°/s limit. However, all the cases exceeding the 6°/s limit were either cases of vertical or oblique PN; there were no cases of horizontal PN exceeding the 6°/s limit. This suggests that while the current criterion is applicable for horizontal PN, it may not be suitable for interpreting cases of vertical and oblique PN. For this reason normative data obtained from larger scale studies are required to confirm the threshold for pathological vertical and oblique PN. Until then, vertical and oblique PN need to be interpreted with some caution and in conjunction with results of other vestibular tests.

Criterion number 2 suggests that clinically significant PN involves persistent PN with SPV greater than 6°/s, which is present in at least five positions or more of the eight to 11 test positions. In this study four participants (22.2%) had persistent PN in five or more test position of the 11 test positions in more than one test session and one participant had PN in all 11 positions in one of the test sessions. Thus if this criterion was applied, 22.2% normal healthy participants would be found to have clinically significant PN. Furthermore, this criterion loses its purpose where a clinician chooses to test in fewer than eight positions in static position testing. Therefore it is apparent that criteria less susceptible to manipulation are needed to determine whether the measured PN is clinically significant. According to Barin (2006), the peak SPV of PN should be used as a sole criterion for pathological PN without fixation and the results of this experiment support this notion.

4.7 Limitations of the study

4.7.1 Participants recruitment

Due to time restrictions non-randomised sampling of participants was used. This could have introduced systematic bias into the study, affecting results of the experiment. Further to this, the majority of the participants (66.7%) were postgraduate students of Audiology. As all of them had undergone static positional testing in the past as a part of their training, it is possible that some of them may have been aware of having PN and for this reason volunteered to participate in the study. Moreover, difficulties were experienced in recruiting adequate numbers of different age categories. As a result, the age-range of participants was not evenly distributed and therefore the test results may not be representative of results of the general population. Two participants had to be excluded due to presence of SN and data of further four participants had to be removed from the analysis due to the poor quality of the recorded data. The loss of the participants may have decreased the power of the results.

4.7.2 Screening

This study used basic screening tool of otoscopy, tympanometry, pure tone audiometry, and the SN test to screen the recruited individuals. However, since no other balance tests, such as the Dix Hallpike manoeuvre or Caloric test, were carried out prior to the start of the testing, it cannot be ruled out that some of the recruited individuals had an unidentified vestibular pathology. Further to this, a medical questionnaire was employed to reveal any other relevant health issues that could affect the test results. This tool is highly subjective and relies on participants' judgment.

There were two participants who admitted to consuming small amount of alcohol 14-15 hours prior to the start of the testing. Participant number three was a 24 years old male who admitted to drinking two units of alcohol 15 hours prior to the testing. However, his PN was not consistent with the third phase of positional alcohol nystagmus (PAN II), as vast majority of his PN cases were direction-fixed and not ageotropic. Furthermore, on re-testing on a different day, when this participant had not consumed any alcohol for 48 hours, PN was still present in four out of five test positions and correlated in magnitude to the previously obtained data. Therefore his data were not removed from the analysis as it clearly represented a normal finding for this participant. Similarly, participant number sixteen, who was a 76 year old lady, consumed three units of alcohol 18 hours prior to the start of testing. This participant had only one isolated case of PN of a low magnitude (1°/s). Also in this instance, the recorded PN was not consistent with PAN II.

4.7.3 Test procedure

There were a number of factors that could have affected the recordings. Firstly, difficulties were experienced with maintaining a secure and stable placement of the VNG goggles on participants' faces throughout the testing. As participants had to move through a high number of different positions in a randomised order, e.g. from the HR position into the HHL position and then into the BRS position, this put strain on the stable position of the VNG goggles. It was not uncommon to have to stop testing in order to correct the position of the VNG goggles and recalibrate between different positions. Some participants had inclination to correct the position of the VNG goggles themselves, and when this was noticed by the tester the VNG system was immediately recalibrated. However, it cannot be ruled out that some of the attempts passed unnoticed. While this would not affect the results of prevalence of PN, the calibration drift may have affected the measured SPV magnitude.

Furthermore, identical mental alerting task was used for everyone. While counting down in fours from 1000 may have been challenging for some, for others the task may not have sufficiently inhibit the brain's nystagmus suppression mechanism (Barber, 1984).

4.7.4 Analysis

Due to the nominal nature of the data, the analysis of prevalence and direction of PN was limited. For this reason, assessment of the nominal data was done mainly by means of graphical representation of the data. Such approach inevitably brings a large degree of subjectivity. Additionally, there is a need for a word of caution for the statistical analysis of the prevalence of PN. Since the nominal data were 'converted' into numeric data using percentages of the total PN prevalence, this may have affected the accuracy of the results. Nonetheless, the results of the statistical analysis using SPSS are supported by the results of quantitative analysis using the Excel program, which clearly demonstrate that PN prevalence was considerably higher in the test sets with mental alerting than in those without mental alerting.

Furthermore, even where numeric data were available, such as SPV magnitudes, the data were abnormally distributed due to many null results of participants with no case of PN in a particular test set. This limited the analysis to the use of non-parametric tests, which are less robust than parametric tests (Field, 2009). Moreover, the large number of null results, which had to be included in the analysis, caused a false increase in SD across responses.

4.8 Clinical significance

One of the main aims of this study was to investigate the effects of mental alerting on PN. Even though no effects of mental alerting on SPV magnitudes were detected, the results suggested that prevalence and repeatability of PN increase when mental alerting is implemented. Since some vestibular clinics across the United Kingdom do not routinely use mental alerting during static positional testing, the results of this study provide greater understanding on how this may affect the test results.

Furthermore, this study highlighted the need for normative data for vertical and oblique PN. While the current threshold for pathological horizontal PN is applicable, the same criterion may not be used for interpreting vertical and oblique PN.

This study has identified some problematic aspects of the static positional testing. Firstly, testing in as many as 11 positions has been found physically challenging even by healthy young participants. Since many patients in vestibular clinics are older people with additional health issues, such as neck or back problems, inclusion of 11 positions seems rather impractical. If the criteria for defining pathological PN using VNG were based on 11 test positions, it would not be possible to interpret accurately results of those individuals who were not physically capable to place themselves into all 11 positions. Thus, it is apparent that a smaller subset of less physically challenging test positions is required. Barin (2008) suggested use of four positions: sitting, supine with the head elevated by 30°, supine position with head turned right, and supine position with head turned left. Where patients experience neck problems, the ‘body right side position’ and ‘body left side position’ could used instead of turning the head to sides. It would also be useful to include the primary position reported by the patient as causing a dizziness problem.

An additional problem with 11 test positions is the practical issue of securing VNG goggles for testing. As the head hanging positions are included in the set of positions, there are different pulls of gravity onto the goggles during the testing. In order to secure the goggles for testing as many as 11 positions, and prevent the need for recalibration during the testing, the head band must be adjusted quite tightly, which may not be comfortable for the patient. Finally, it has been observed that one static positional test involving 11 positions requires approximately 15 minutes to be conducted. This may not be an economical use of time, especially within hospital departments that work within strict time restrains.

4.9 Future research

This study tested three main hypotheses and contributed to knowledge about static positional testing with regards to effects of mental alerting, within test session repeatability, and effects of different head and body positions on prevalence and magnitude of PN. However, there are still a number of aspects of the test that need to be examined.

Firstly, as already discussed, normative data need to be obtained for vertical and oblique PN. At the present the 6°/s limit is used in conjunction with VNG regardless the type of PN, which may not provide accurate assessment of the results. While the 'traditional' 6°/s limit is still applicable to horizontal PN using VNG, the limit is potentially too high and should be revisited as well.

Since this study tested only few participants older than 50 years, the future study should focus on comparison of different age categories. The study should be of a greater size in order to provide more powerful statistical analysis.

Another study replicating testing with all 11 positions would also be beneficial. This would confirm whether there is truly no predominant position generating the highest rates of PN.

It would be interesting to see what the effects of low consumption of alcohol on prevalence of PN in the normal healthy population are. This is because a highly screened sample of normal healthy participants may not be representative of a typical patient in a vestibular clinic.

Based on the already gathered evidence, recommended procedure for the static positional testing should be drawn in order to provide a universal technique for conducting the test. This would enable a clinician to interpret the test results more confidently and also allow easier comparison of results across different studies.

CHAPTER 5- CONCLUSION

- Persistent PN, including horizontal, vertical, and oblique PN, can be frequently found in healthy normal population in static positional testing using VNG.
- Mental alerting increases prevalence of PN in healthy normal population; however, no effects of mental alerting on SPVs have been detected.
- There is only a weak to modest within-session repeatability of PN, which is however greater when mental alerting is implemented.
- There is a good within session repeatability of the SPV magnitudes.
- There is no evidence that one particular test position would generate consistently higher rates of PN than others in healthy normal population.
- There is a need for refinement of the criteria for pathological PN, especially for vertical and oblique PN.
- There is a need for a defined procedure for the static positional test for use in clinics.

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APPENDIX A

Health Questionnaire

Prevalence of positional nystagmus during static positional testing in normal healthy population using video-nystagmography

Experimenter: Irena Svandelkova

Participant's name:
Age:
Gender:

Please, circle the appropriate answer

1. Have you ever suffered from balance problems, such as unsteadiness, dizziness, or giddiness? If yes, please provide detail.
YES NO

2. Do you feel you have any problems with your hearing? If yes, please provide detail.
YES NO

3. Have you ever had any problems with your ears in terms of recurrent infections? If yes, please provide detail.
YES NO

4. Have you ever had any ear surgery? If yes, please provide detail.
YES NO

5. Do you suffer from any eyesight problem other than that corrected by glasses/ contact lenses? If yes, please provide detail.
YES NO

6. Do you suffer from any neck or back problems? If yes, please provide detail.
YES NO

6. Do you suffer from arthritis (swelling and stiffness of joints)? If yes, please provide detail.
YES NO

7. Do you suffer from any mobility problems? If yes, please provide detail.
YES NO

8. Do you have or have you ever had any cardiovascular problems (high blood pressure, heart problems, blackouts, or stroke)? If yes, please provide detail.
YES NO

9. Do you suffer from any serious illness? If yes, please provide detail.
YES NO

10. Do you currently take any medication on a regular basis? If yes, please provide detail.
YES NO

11. Do you smoke?
YES NO
If yes, have you smoked within the past two hours? YES NO

12. Have you consumed any alcohol within the past 24 hours?
YES NO

APPENDIX B

INFORMATION SHEET FOR PARTICIPANTS

Prevalence of positional nystagmus during static positional testing in normal healthy population using video-nystagmography

Experimenter: Irena Svandelkova

Purpose of the study:
This study is investigating commonness of abnormal eye movements known as positional nystagmus (PN) during static positional test in normal healthy individuals. There is evidence that whilst PN typically occurs in people with balance problems, adults with no complain of dizziness can also manifest PN.

What the study entails
The study involves one session in total, which consists of four sets of static positional test. During this test, your head and body will be slowly and gently moved from one position to another (11 positions in total) and then statically maintained in each position for 30 seconds whilst your eyes will be monitored using video-goggles (See Figure 1 below). This study aims to look at prevalence of PN, effects of mental alerting (that is simple mental arithmetic) on its prevalence and magnitude, as well as its repeatability within one test session. For this reason two sets of the static positional test will be carried out with mental alerting and two sets will be carried out without mental alerting.

Before the start of the testing
Before the testing is commenced, your ears will be checked for any abnormalities, such as excessive wax or external or middle ear infection, using otoscopy and your hearing will be tested using pure tone audiometry. Middle ear function will be assessed using tympanometry. The whole session will take approximately one hour.

Participants
Participants eligible for this study must be between ages of 20-80 inclusive and fulfil these criteria: no history of balance problems, hearing difficulties, recurrent ear infections, neck of back problems, mobility problems, or cardiovascular problems. All participants must refrain from smoking at least two hours and consuming alcohol at least 24 hours prior the start of testing.

Where the study takes place
This study will take place in the Vestibular Room on the 4th floor of the Institute of Sound and Vibration Research (ISVR) in the University of Southampton.

If you feel that you would like to participate in this study, please contact me on a number 07838043063 or email me on is405@soton.ac.uk.

Many thanks.

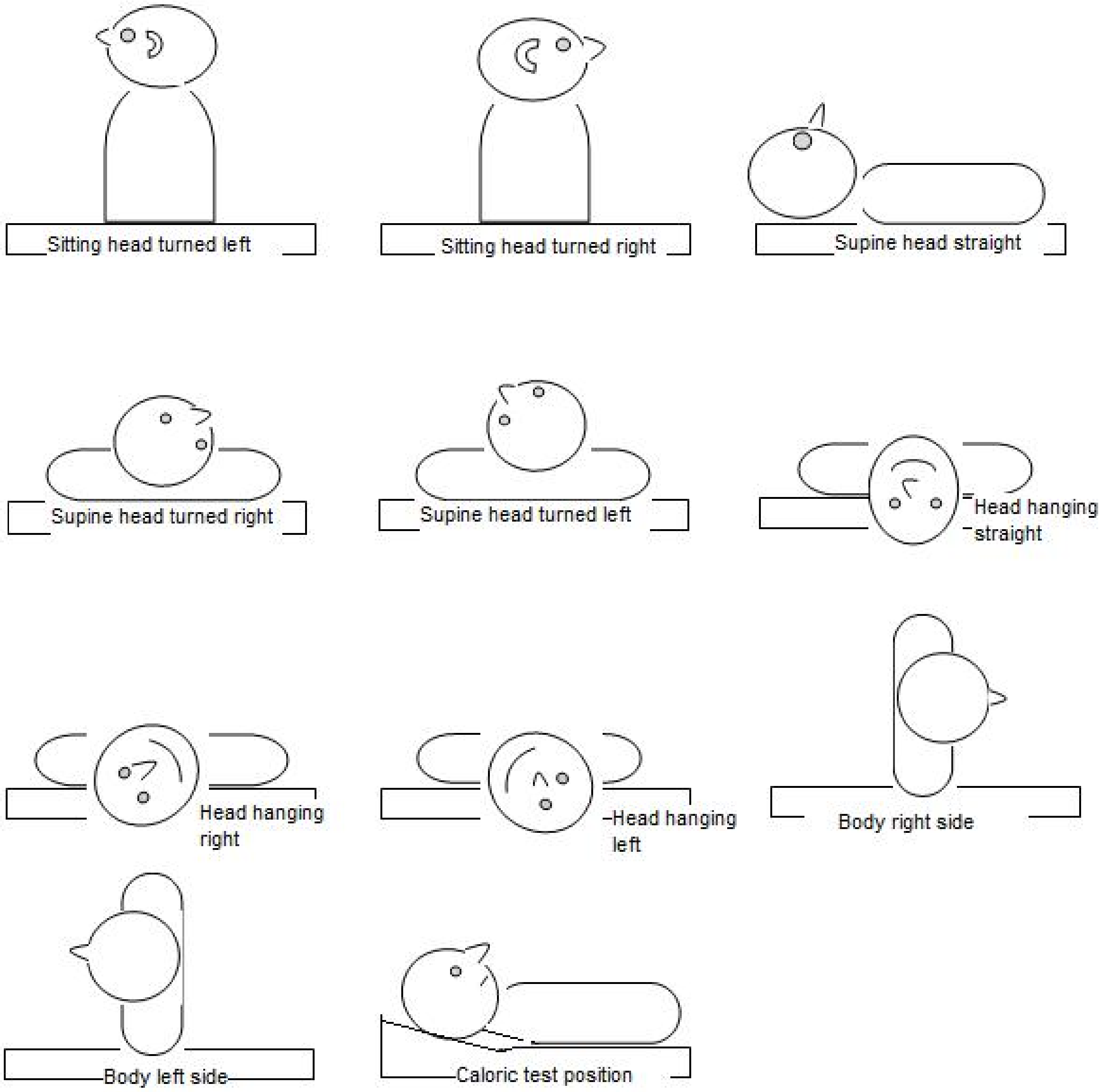

Figure 1: The 11 test positions used in static positional test

APPENDIX C

Consent form to be completed by adult subjects taking part in an experiment
(Adults are 18 years of age or older.)

Exposure Number: . 1106

University of Southampton
Institute of Sound and Vibration Research

Before completing this form, please read the list of contra-indications which has been provided by the experimenter on the reverse of this form.

This consent form applies to a subject volunteering to undergo an experiment for research purposes. The form is to be completed before the experiment commences.

I, ...

of ....
(address or department)

consent to take part in .... **Prevalence of positional nystagmus during static positional testing in normal healthy population using video-nystagmography** .....

to be conducted by....... **Irena Svandelkova** ....

during the period .... **11.07.2010** .... to .... **31.08.2010** .... 19 ....

The purpose and nature of this experiment have been explained to me. I understand that the investigation is to be carried out solely for the purposes of research. I am willing to act as a volunteer for that purpose on the understanding that I shall be entitled to withdraw this consent at any time, without giving any reasons for withdrawal. My replies to the above questions are correct to the best of my belief, and I understand that they will be treated by the experimenter as confidential.

Date: .... Signed: ....
(Volunteer subject)

I confirm that I have explained to the subject the purpose and nature of the investigation which has been approved by the Human Experimentation Safety and Ethics Committee.

Date: .... Signed: ....
(Researcher in charge of experiment)

This form must be submitted to the Secretary of the Human Experimentation Safety and Ethics Committee on completion of the experiment.

APPENDIX D- RAW DATA KEY

Headings

A1= First test set with mental alerting

A2= Second test set without mental alerting

PT= Participant number

P= Presence of PN (0= PN absent, 1= PN present)

D= Direction of PN

SPV= (mean peak) Slow phase velocity

Type of PN

HLB= Horizontal left-beating

HRB= Horizontal right-beating

ODLB= Oblique down and left beating

OULB= Oblique up and left beating

OURB= Oblique up an right beating

VDB= Vertical down-beating

VUB= Vertical up-beating

Positions

HR= Sitting head turned right

HL= Sitting head turned left

SHS= Supine head straight

SHR= Supine head turned right

SHL= Supine head turned left

HHS= Head hanging straight

HHR= Head hanging right

HHL= Head hanging left

BRS= Body right side

BLS= Body left side

C= Caloric test position

APPENDIX D- RAW DATA

	1. HR												**2. HL**												**3.SHS**					
	A1			**A2**			**NA1**			**NA2**			**A1**			**A2**			**NA1**			**NA2**			**A1**			**A2**		
PT	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*
1	0			0			0			0			0			0			0			0			0			0		
2	0			0			0			0			0			0			0			0			0			0		
3	1	VUB	4	0			0			1	OULB	6.7	1	OULB	5	1	HLB	2.3	1	OULB	6.4	1	OULB	5.5	1	OULB	6	1	OULB	7.2
4	0			0			0			0			0			0			0			0			0			0		
5	0			0			0			0			0			0			0			0			0			0		
6	0			0			0			0			0			0			0			0			1	VUB	4	0		
7	1	VUB	4.8	1	VUB	4.4	1	VUB	2.3	1	VUB	7	1	VUB	2.4	1	VUB	4.3	1	VUB	3.6	1	VUB	3.4	1	VUB	7.2	1	VUB	8
8	0			0			0			0			0			0			0			0			1	HLB	3.3	1	HLB	2.8
9	0			0			0			0			0			0			0			0			0			0		
10	0			0			0			0			1	HLB	3	0			0			0			1	VUB	3.5	1	OULB	3.8
11	0			0			0			0			0			0			0			0			0			0		
12	0			0			0			0			0			0			0			0			0			1	VUB	3.8
13	0			0			0			0			0			0			0			0			1	VUB	3.5	1	VUB	3.6
14	0			0			0			0			0			0			0			0			0			0		
15	0			0			0			0			1	HRB	1.5	0			1	HRB	3.4	0			0			0		
16	1	HLB	1	0			0			0			0			0			0			0			0			0		
17	0			0			0			0			0			0			0			0			0			0		
18	0			0			0			0			0			0			0			0			0			0		

APPENDIX D- RAW DATA

						4.SHR														**5.SHL**									
NA1			**NA2**			**A1**			**A2**			**NA1**			**NA2**			**A1**			**A2**			**NA1**			**NA2**		
P	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			1	HLB	2.1
1	OULB	9.4	0			1	OULB	7	1	OULB	9.6	1	OULB	8.2	1	OULB	9.6	0			1	OULB	4.6	0			1	OULB	12
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			1	VUB	4.7	1	VUB	4.2	1	VUB	2.1	0			1	VUB	4.8	0			1	VUB	4	0			0		
1	VUB	5.3				1	VUB	11	1	OURB	13	1	VUB	6.7	1	VUB	8.9	1	VUB	5.7	0			1	VUB	6.2	1	VUB	7
0			0			0			0			0			0			0			1	HLB	2.8	0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			1	VUB	3.8	1	HLB	2.4	0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
1	VUB	3.4	0			0			0			0			0			0			0			1	VUB	4	0		
1	VUB	1.7	1	OULB	0.8	0			0			0			0			0			0			0			0		
0			0			0			1	VUB	2.3	0			0			0			0			0			0		
1	HRB	3.6	0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			1	HLB	1.4	0			0			0			0			0			0			0			0		

APPENDIX D- RAW DATA

6.HHS												7.HHR												8.HHL					
A1			**A2**			**NA1**			**NA2**			**A1**			**A2**			**NA1**			**NA2**			**A1**			**A2**		
P	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			1	VDB	5.7	1	ODLB	3.8	0			1	HLB	3.2	1	HLB	3.6
1	VUB	5	1	OULB	6	1	OULB	7.5	1	OULB	9.4	0			1	OULB	9.1	0			1	OULB	8	1	OULB	6.2	0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			1	VUB	5.7	0			1	VUB	4.4	0			0			1	VUB	3.8	0		
1	VUB	7	1	VUB	4.6	0			0			1	VUB	5.5	1	VUB	8.6	0			1	VUB	4.8	1	OURB	9.6	0		
0			0			0			0			0			0			0			0			1	HLB	2.3	0		
0			0			0			0			0			0			0			0			0			0		
1	VUB	2.6	0			0			0			0			1	OULB	5.2	0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			1	HRB	3	0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		

APPENDIX D- RAW DATA

						8.BRS												**10.BLS**											
NA1			**NA2**			**A1**			**A2**			**NA1**			**NA2**			**A1**			**A2**			**NA1**			**NA2**		
P	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*
0			0			0			0			0			0			0			0			0			0		
1	ODLB	3.4	1	HLB	3.8	0			0			0			0			1	HLB	2.4	1	HLB	2.3	0			0		
0			0			1	OULB	3.2	0			1	OULB	3.2	0			1	OULB	2.8	1	OULB	3.8	1	OULB	3.4	0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			1	VUB	2.8	0			1	VUB	3	1	VUB	2.3	0			1	VUB	4.6	0			0			0		
0			1	VUB	6.2	1	VUB	7.2	1	VUB	6	1	VUB	4.8	0			1	OURB	5	1	OURB	4.8	1	OURB	6.2	1	VUB	9
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			1	OULB	3.6	1	HLB	3.3	0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			1	HLB	0.8	0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			1	HRB	3	0			1	HRB	5.7	1	HRB	3.8	0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		
0			0			0			0			0			0			0			0			0			0		

APPENDIX D- RAW DATA

11.C

A1			**A2**			**NA1**			**NA2**		
P	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*	*P*	*D*	*SPV*
0			0			0			0		
0			0			0			0		
1	OULB	6.8	1	OULB	7.2	1	OULB	6	0		
0			0			0			0		
0			0			0			0		
1	VUB	4	0			0			0		
1	VUB	8	1	OURB	8	1	OURB	8.6	1	VUB	3.8
0			0			0			0		
0			0			0			0		
1	VUB	2.6	1	OULB	4.4	0			0		
0			0			0			0		
0			0			0			0		
0			0			1	VUB	2.1	0		
0			0			0			0		
0			0			0			0		
0			0			0			0		
0			0			0			0		
0			0			0			0		