Development and Maturation of Global Motion Sensitivity in Children of Kathmandu

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A thesis submitted to Buskerud University College for the degree of Master of Philosophy

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Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other University College, or other institution of learning.

Mahesh Raj Joshi

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Copyright statement

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List of Figures and Tables

Abbreviations

RDK: Random Dot Kinematogram

MCT: Motion Coherence Threshold

MAR: Minimum Angle of Resolution

ANOVA: Analysis of Variance

LGN: Lateral Geniculate Nucleus

V1: Primary Visual Cortex

MT: Middle Temporal Cortex

MST: Medial Superior Temporal Cortex

STPa: Anterior Superior Temporal Polysensory Area

VIP: Ventral Intraparietal Area

M1: Motor cortex

Abstract

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Introduction:

Global motion processing is an essential part of visual perception involving higher cortical areas. The motion coherence threshold (MCT) is used to evaluate global motion processing. Previous studies have investigated the development of translational optic flow processing in children but no study has yet evaluated MCT for radial optic flow. Previous studies have proposed different channels for processing slow and fast motion. The aim of this study was to investigate the development and maturation of optic flow processing in children and to explore the effect of speed and different types of optic flow stimuli.

Methods:

A total of 125 children, aged from 6 to 16 years and 24 adults, with normal ocular health, participated. The children and adults were evaluated with optic flow patterns at a relatively fast (5.48°/s) and a relatively slow (1.56°/s) speed at a Michelson contrast level of 75%. A pilot study involving four observers was carried out to establish the optimum values for speed and contrast to be used in the main study. A random dot kinematogram stimulus with 100 dots was used in this study. The Observer's task was to discriminate rightward and leftward translation, clockwise and anti-clockwise rotation and expanding and contracting radial optic flow patterns.

Results:

Children showed a reliable improvement in radial MCT with age, at both speeds. Surprisingly, the radial MCT of 16-year-old children did not reach the adult level, although it was closer to the adult value at the higher speed than at the lower speed ($p<0.05$). There was no significant difference in translational MCT for 8, 12 and 16-year-old children compared with adults. The adults showed better MCT for the higher than the lower speed, for all three optic flow patterns ($p<0.05$). MCT for translational flow was worse than MCT for the radial optic flow pattern at the lower speed ($p<0.05$) but similar at the higher speed ($p>0.05$). MCT was similar for a wide range of contrast levels and relatively high speeds in the pilot study.

Conclusion:

Sensitivity to radial optic flow develops with age. Younger children are poorer at detecting radial optic flow than older children and adults, with development continuing until late childhood. Sensitivity to translational MCT matures earlier. The development of radial MCT also differs with different stimulus speeds. Sensitivity to all optic flow patterns is greater at higher speeds. Sensitivity to the three optic flow patterns is similar at the higher speed but not at the lower speed. Differences in sensitivity to optic flow at lower and higher speeds, together with the varied development of radial optic flow at these speeds suggests that different motion perception channels are involved in processing slow and fast speeds.

Key Words: Motion coherence threshold, Optic flow, Development, Maturation, Children, Speed

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1.0 General Introduction

Motion perception is essential for our overall visual perception and our response to changes in the environment. Motion is perceived due to changes in the spatial distribution of light over time (Schwartz, 2010) and specifies the direction and speed of objects. Motion accentuates the perception of the shape of an object (shape from motion) and provides information on people's body movement (biological motion) and facial expressions (Randolph, Emily, & Robert, 2003; Sekuler & Blake, 2006). It also helps in the detection of various small and camouflaged objects in the environment and in three-dimensional perception (structure from motion) by the process called the kinetic depth effect (Palmer, 1999; Sekuler & Blake, 2006). When crossing the road, it is essential to gauge the speed of vehicles and other surrounding objects. When playing or cycling, information on self-motion and motion within our surroundings becomes essential. Loss of motion perception (motion blindness or akinetopsia) as experienced in selective bilateral brain damage leads to difficulties in performing even basic tasks such as filling a glass with water (Zihl, von Cramon, & Mai, 1983).

1.1 Optic Flow

The pattern of motion experienced through head and eye movements and through self-motion in an environment is called optic flow (Bruce, Green, & Georgeson, 2003; Raffi & Siegel, 2004; Vaina & Rushton, 2000). During locomotion, a person not only needs information from a small area representing local motion, but they also require information about the motion of objects in the surrounding areas. This type of processing of information from a large visual field is referred to as global motion perception. In addition to information from the three-dimensional environment, global optic flow processing has to deal with changes brought about by self-motion (Palmer, 1999; Vaina & Rushton, 2000). Information from optic flow is essential for navigation and for avoiding obstacles and collisions in all forms of human locomotion (Raffi & Siegel, 2004; Vaina & Rushton, 2000).

When humans move within their environment radial optic flow is experienced. The radial flow perceived is that of expansion while moving towards an object and contraction while moving away from it (Figure 2c). The pattern of optic flow also changes with eye or head movements. Eye movements create translational motion across the retina and head movements add a rotational component (Figure 2 a,b). Translation is also experienced with the linear motion of an object between two points in space. The other type of motion experienced is spiral motion, which is processed by detection of its individual circular and radial components (Burr, Badcock, & Ross, 2001; Tohyama & Fukushima, 2005). Hence the three components, namely translational, radial and rotational motion can represent most of the motion patterns experienced in the visual world.

Thus optic flow is an important and readily experienced motion phenomenon in our daily life which provides information regarding both self-motion and the motion of different objects within the environment. Information from optic flow allows us to determine self-speed and direction, as well as time to collision with other objects.

1.1.1 Types of Global Optic Flow

Among the various optic flow patterns experienced in daily life, each contributes to our sense of motion. Translation involves two-dimensional motion processing and occurs due to eye movements and linear tracking. Radial and rotational optic flow deals with the three-dimensional aspects of the visual world. Radial flow observed on a two-dimensional screen appears to be moving in depth (Bex & Makous, 1997). In addition to these differences, there is also a difference in the site of motion processing for these patterns, with the middle temporal area involved in processing translation while the middle superior temporal area and higher cortical structures are involved in processing radial motion. The details of optic flow processing are described in Chapter 1.2. The differences between translational flow and other optic flow patterns suggest different sensitivity to these patterns. Psychophysical studies have evaluated the efficiency of the visual system to process different types of optic flow patterns. These studies have evaluated optic flow based on first and second order motion (Aaen-Stockdale, Ledgeway, & Hess, 2007; Bertone & Faubert, 2003; Blake & Aiba, 1998). The perception of motion based on changes in luminance is first order (Fourier) motion and perception based on

contrast or texture is second order (non-Fourier) motion (Palmer, 1999). Studies that have measured sensitivity to different types of first order optic flow suggest that flow type has little or no effect on perception. Sensitivity to complex motion such as radial and circular stimuli has been observed to be equivalent to sensitivity to translational motion in several studies (Aaen-Stockdale, et al., 2007; Bertone & Faubert, 2003; Blake & Aiba, 1998). Other studies, however, have suggested that sensitivity differs according to the type of optic flow pattern, with better sensitivity for rotational and radial flow than for translational flow (Freeman & Harris, 1992; Lee & Lu, 2010). Among the more complex motion types, the threshold for radial motion is reported to be significantly lower than for circular motion (Beardsley & Vaina, 2005).

1.2 Motion Processing

Motion is processed by a complex but relatively well understood neural pathway. Single subject analysis of functional magnetic resonance imaging data has reported as many as 17 anatomically distinct brain areas being activated by motion (Sunaert, Van Hecke, Marchal, & Orban, 1999). Motion processing is believed to follow a hierarchical system, starting with the stimulation of retinal cells and the lateral geniculate nucleus (LGN) and subsequent processing in primary visual cortex (V1) and other higher centres in the middle temporal area (MT) and the middle superior temporal area (MST) resulting in global motion perception (Tohyama & Fukushima, 2005).

Retinal ganglion cells: parasol (magno), midget (parvo) and konio cells project to the LGN (Albright, 1993; Schwartz, 2010). Among these retinal cells, magno cells are well suited for motion processing, with low spatial resolution and no response to colour, as well as high sensitivity to luminance and speed (Palmer, 1999). The information from magno cells is processed through the magnocellular pathway to LGN and ultimately to the primary visual cortex, V1 (Albright, 1993; Palmer, 1999).

In humans, V1 is regarded as the site where the first stage of motion processing occurs, signalling direction of motion in local fields (Randolph, et al., 2003; Smith, Greenlee, Singh, Kraemer, & Hennig, 1998). Layer 4Cα of V1 receives the majority of its input from the magnocellular pathway (Albright, 1993). About one third of neurons in V1 are reported to be

direction selective (Randolph, et al., 2003). However, V1 responds to all directions of motion and to different dynamic stimuli and this responsiveness is accounted by the spatio temporal change in image. Thus V1 neurons cannot be inferred to have true sensitivity to motion (Randolph, et al., 2003; Smith, et al., 1998). The input from V1 cells are further processed in MT, MST and various other areas of the extra-striate cortex.

Motion processing continues in area MT, which mainly processes input from the magnocellular layer of LGN (Maunsell, Nealey, & DePriest, 1990). Area MT is well suited for motion processing, as approximately 80% of its neurons are direction selective (Maunsell & Van Essen, 1983) with larger receptive fields than V1 (Smith, et al., 1998). The importance of MT is revealed by studies that show drastically reduced motion sensitivity when MT is compromised with isolated lesions (Albright, 1993). The larger receptive fields allow MT to process information from a wider field of view. Hence the input from V1 with information about local motion is further processed in MT, resulting in the perception of global motion. Translational global motion is processed in MT (Morrone et al., 2000; Tohyama & Fukushima, 2005); however, more complex optic flow patterns such as radial motion and rotational motion are processed in the higher cortical areas of MST and beyond. For motion perception, the evaluation of changes in direction of moving objects is important. It is equally important to determine the speed of the objects. V1 neurons are not sensitive to image speed, in fact speed selectivity is first seen in the neurons of area MT (Albright, 1993; Perrone & Thiele, 2001; Smith, et al., 1998). The optimal speed preference of MT is reported to be approximately 2°/s to 256°/s (Albright, 1993). Hence MT is capable of processing both direction and speed.

Area MST has neurons with larger receptive fields than MT that extend over both contralateral and ipsilateral visual hemifields (Greenlee, 2000; Morrone, et al., 2000; Tohyama & Fukushima, 2005). The larger receptive fields in MST provide global perception and make MST neurons well suited for processing complex motion pattern such as radial and rotational optic flow (Morrone, et al., 2000; Tohyama & Fukushima, 2005). The neurons in MST are also sensitive to different optic flow pattern speeds (Duffy & Wurtz, 1991, 1997). Almost two third of the neurons in MST have been reported to respond to speeds of 10°/s to 80°/s, with a preference for higher speeds (Duffy & Wurtz, 1997). The direction and speed of complex optic flow patterns are hence

processed in MST. In addition to MST, areas of ventral intraparietal (VIP) cortex, anterior superior temporal (STPa) cortex and motor cortex (M1) have also been associated with optic flow processing (Raffi & Siegel, 2004; Randolph, et al., 2003). The areas that are involved in optic flow processing respond selectively to the direction of rotational and radial optic flow (Tanaka and Saito, 1989) with a preference for radial optic flow. The cells in the dorsolateral region of MST have more expansion-tuned than rotation-tuned neurons (Duffy & Wurtz, 1991). Similarly, the neurons in VIP, STPa and M1 also prefer radial expansion to other patterns of optic flow (Raffi & Siegel, 2004). The preference for expansion over other optic flow patterns is consistent with the needs of human daily life, as humans are most involved in forward movement which stimulates expansion radial flow (Raffi & Siegel, 2004).

Apart from the hierarchical system proposed, there are various other brain areas which are motion sensitive. The presence of these areas suggests multiple channels for motion perception, not just the classic V1-MT-MST complex. Area V2 contains high numbers of directionally selective cells and it projects to area MT (Vaina & Rushton, 2000). Similarly, the dorsal part of the brain in the parietal lobe (areas V3 and V3A) also respond to motion stimuli with a greater degree of direction selectivity than V1 (Smith, et al., 1998; Tootell et al., 1997).

1.3 Development of Visual Functions

Various visual functions develop and mature during infancy and reach adult levels at different ages (Ellemberg, Lewis, Liu, & Maurer, 1999; Gordon & McCulloch, 1999; Hong & Park, 2008; Zanker, Mohn, Weber, Zeitler-Driess, & Fahle, 1992). Although there have been many studies detailing the development and maturation of various visual aspects at different ages, they have mostly been limited to the evaluation of spatial vision and few have explored the development of temporal vision, specifically motion sensitivity. It has been suggested that Vernier acuity (Zanker, et al., 1992) ,distance stereo acuity (Hong & Park, 2008), grating acuity and letter acuity (Ellemberg, et al., 1999) are adult-like by the age of 4 to 6 years. Contrast sensitivity has been reported to mature slightly later, by the age of 5 to 8 years, depending upon the stimulus used for evaluation (Ellemberg, et al., 1999; Rogers, Bremer, & Leguire, 1987; Scharre, Cotter, Block, & Kelly, 1990). However, some aspects of visual perception continue to develop even in

late childhood. For example, dynamic visual acuity matures at the age of 15 years (Schrauf, Wist, & Ehrenstein, 1999). Similarly, spatial integration shows improvement until 14 years of age (Kovacs, Kozma, Feher, & Benedek, 1999). The fact that some visual functions continue to develop until late childhood highlights the relative plasticity of the visual system.

1.3.1 Development of Motion

Different aspects of motion sensitivity develop and mature at different ages (Parrish, Giaschi, Boden, & Dougherty, 2005; Spencer et al., 2000). Infants as young as two months old are able to detect limited visual motion with some sensitivity to direction discrimination (Brosseau-Lachaine, Casanova, & Faubert, 2008; R. O. Gilmore, Hou, Pettet, & Norcia, 2007). As with other visual functions, the development of motion has been reported to be affected by early visual deprivation, for example due to congenital cataracts (Ellemberg et al., 2005).

Infant sensitivity and preference for moving stimuli does not necessarily imply that the infant's visual system can extract complete motion information. Hence, while the preference for a moving object over a stationary one is present from infancy, the ability to perform more complex motion tasks develops at various ages and exhibits different patterns of maturation. Temporal contrast sensitivity at higher frequencies and critical flicker frequency are adult-like by the age of four years, while at lower frequencies they are still developing, reaching the adult level at the age of seven years (Ellemberg, et al., 1999). Global motion perception has been evaluated in different age groups. Five-year-olds have been found to be immature for global motion, compared with adults (Ellemberg et al., 2004). Studies evaluating the motion coherence threshold (MCT) have reported an improvement in threshold with increasing age from 5 to 11.5 years (Annaz et al., 2010). Although there is consensus that motion related functions improve with age, the age at which they mature depends on the type of motion task being evaluated. In a global translational motion task, children aged 7 to 8 years and above had coherence thresholds similar to adults, whereas children aged 3 to 6 years had higher coherence thresholds (Parrish, et al., 2005). Some studies have, however, reported that MCT for translational motion only reaches adult levels by the age of 10 to 11 years (Gunn et al., 2002; Spencer, et al., 2000). Similarly, five–year-olds have been reported to be immature for local motion (Ahmed, Lewis, Ellemberg, & Maurer, 2005) with immaturity persisting even at the age of

10 years (Armstrong, Maurer, & Lewis, 2009). Other aspects of motion development also mature at various ages. Sensitivity to motion defined shapes, for example, is less mature for 5 to 6 year-olds than for 11 to 12 year-olds (Parrish, et al., 2005) and sensitivity for motion defined letters is adult-like by the age of 7 years (Giaschi & Regan, 1997).

1.3.2 Development of Optic Flow

Development of optic flow in infants has been evaluated in many studies (Brosseau-Lachaine, et al., 2008; R. O. Gilmore, et al., 2007; Shirai, Kanazawa, & Yamaguchi, 2008; Wattam-Bell, 1996) but only a few have investigated the development of optic flow in older children (Gunn, et al., 2002; Spencer, et al., 2000). All these studies show that rudimentary sensitivity to optic flow discrimination is present from infancy. An electrophysiological study evaluating visual evoked potential (VEP) responses reported higher sensitivity to translational than radial motion in infants (R. O. Gilmore, et al., 2007). Different studies have also investigated infants' sensitivity to optic flow patterns using a forced choice preferential looking technique. One-month-old infants could differentiate between a moving and a static pattern, but showed no sensitivity to direction for horizontal translation at a wide range of velocities (Wattam-Bell, 1996). Some Studies have suggested that a preference for radial motion develops in infants after two to three months. Shirai et al (2008) compared radial and translational flow patterns in two and three month-old infants. They reported limited ability for discrimination at two months which improved by three months for slower speeds. Similarly, evaluation of the development of radial optic flow sensitivity in infants aged 2 to 8 months reported a steady improvement with age, with a preference for radial expansion rather than radial contraction (Brosseau-Lachaine, et al., 2008).

Studies of the development of translational optic flow sensitivity in older children have reported adult-like levels in children aged 8 to 11 years (Gunn, et al., 2002; Parrish, et al., 2005; Spencer, et al., 2000). No other study, to our knowledge, has explored the sensitivity and development of MCT for complex optic flow patterns in children. Studies in adults have reported a decrease in MCT with age (Allen, Hutchinson, Ledgeway, & Gayle, 2010; Billino, Bremmer, & Gegenfurtner, 2008). In a study that evaluated different types of optic flow pattern perception, there was a substantial decline in threshold for translation, while the radial threshold was reported to be stable throughout the life span from 20 to 82 years of age (Billino, et al., 2008).

Similarly, evaluation of the effect of speed reported a significant decline with age in translational MCT for relatively slow and medium speeds, but not for faster speeds (Snowden & Kavanagh, 2006).

Different motion related functions mature to adult levels at different ages. Although there have been some studies evaluating different motion related functions, as discussed above, very few have evaluated the development of higher motion functions, such as global optic flow processing, in children. Functions such as dynamic acuity and spatial integration, which require higher cortical processing, are reported to mature at a later age (Kovacs, et al., 1999; Schrauf, et al., 1999). Complex optic flow perception also requires higher cortical processing. Hence the evaluation of complex optic flow perception could provide important information on how the motion related channels of higher cortical structures develop in children.

1.4 Measurement of Global Motion

Different stimuli have been used to measure the sensitivity of the visual system to motion. Random dot kinematograms (RDKs) are the most commonly used stimuli for evaluating motion related functions (Allen, et al., 2010; Blake & Aiba, 1998; Rizzo, Nawrot, Sparks, & Dawson, 2008; Simmers, Ledgeway, Hess, & McGraw, 2003; Snowden & Kavanagh, 2006). Other stimuli that have been used include sinusoidal gratings (Ahmed, et al., 2005; Armstrong, et al., 2009), motion defined letters and shapes (Giaschi & Regan, 1997; Hayward, Truong, Partanen, & Giaschi, 2011) and random gabor kinematograms (Ellemberg, et al., 2004; Lee & Lu, 2010). Different stimuli have been used to stimulate motion responsive regions in the brain, to investigate the limits of motion perception through threshold evaluation in patients with various disorders and to investigate the development of motion sensitivity in childhood.

It is also known that MCT evaluates the global motion processing of optic flow, which occurs in higher visual cortical areas (including MT and MST). The RDK has been used for this purpose. In a study designed to localise the area responsive to coherent motion (Braddick et al., 2001), area MT and beyond was more stimulated by coherent motion than by noise elements. By contrast, area V1 showed greater activation to random noise than to coherent motion.

1.4.1 Random Dot Kinematogram and Motion Coherence Threshold

In an RDK stimulus, individual elements move in a random direction with respect to each other (Figure 1). MCTs are determined by measuring the minimum number of coherently moving elements required for accurate detection or discrimination of the direction of motion. The coherently moving dots, also called signal dots, move in a certain direction or within a range of directions. The remaining dots are called noise dots and move randomly. When the proportion of signal dots is high, dots in the RDK appear to move coherently in the general direction of those signal dots. When the signal dots comprise only a small fraction of the RDK, the sense of motion coherence is weak or may be absent. The individual elements in the RDK follow a defined direction for a certain length of time and then randomly reappear in a different area of the stimulus. It is hence not possible to determine the overall direction of the stimulus by tracking only a few dots, rather the observer must evaluate the direction of the whole pattern of dots. The integration of information from different elements in the stimulus represents the global motion of the elements. The human visual system is very sensitive to coherent motion. It is capable of determining the direction of coherent motion with a threshold as low as 5%, under ideal conditions (Blake & Aiba, 1998; Bruce, et al., 2003). A schematic representation of a translational RDK with different levels of motion coherence is given in Figure 1.

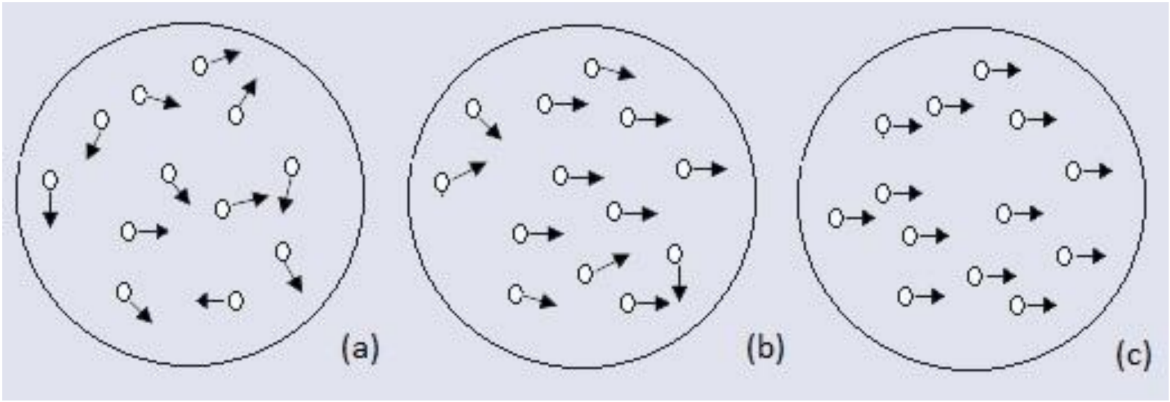

Figure 1: Schematic representation of a random dot kinematogram showing (a) 0% coherence, (b) 50% coherence and (c) 100% coherence of translating dots moving to the right.

Different properties of RDKs, such as speed and contrast, affect MCT (Aaen-Stockdale, et al., 2007; Allen, et al., 2010; Edwards, Badcock, & Nishida, 1996; Snowden & Kavanagh, 2006). Several studies have reported that the speed of the elements is an important factor in

determining MCT. Evaluation of both local and global motion at different speeds has shown that sensitivity is greater at faster speeds for young children and adults (Ahmed, et al., 2005; Ellemberg, et al., 2005; Ellemberg, et al., 2004; Snowden & Kavanagh, 2006).

The difference in sensitivity to faster and slower speeds suggests that the visual system might process different speeds through different mechanisms. Studies have reported evidence for independent channels for detection of slower and faster motion (Edwards, Badcock, & Smith, 1998; Heinrich, van der Smagt, Bach, & Hoffmann, 2004; Khuu & Badcock, 2002). Using translational, radial and rotational optic flow patterns, psychophysical studies have found that detection mechanisms at different speeds are independent of each other (Edwards, et al., 1998; Khuu & Badcock, 2002). These studies evaluated the effect of noise dots of different speeds on the detection of slower and faster signal dots. They reported that for all three optic flow patterns, discrimination of slower signal speeds are only affected by relatively slow moving noise dots. Similarly, discrimination of faster signal speeds is only affected by noise dots that move at a similar speed to the signal dot speed. This interaction of slow signal speeds with slow noise dots and fast signal speeds with fast noise dots provides evidence that these two systems work differently and are independent of each other (Edwards, et al., 1998; Khuu & Badcock, 2002). Similarly, electrophysiological studies with VEP recordings have isolated cortical areas which are selectively activated by slower speeds and other areas that are activated by both slow and fast speeds, which supports the theory of two independent channels for slower and faster speeds, as proposed by the behavioural studies (Lorteije, van Wezel, & van der Smagt, 2008). However, a more recent study (van Boxtel & Erkelens, 2006) evaluated multiple signal speeds, instead of just two as used in previous studies. This study investigated four different speeds and found considerable overlap of processing. The authors proposed a single motion system with mechanisms well tuned for different speeds and differential sensitivity to slow and fast speeds.

The contrast of the dot elements also affects the discrimination of optic flow patterns (Aaen-Stockdale, et al., 2007; Allen, et al., 2010; Edwards, et al., 1996; Simmers, Ledgeway, Mansouri, Hutchinson, & Hess, 2006). These studies have reported that MCT for different optic flow patterns remains unaffected by changes in contrast above a critical value, while below this value there is deterioration in MCT. The contrast level at which the deterioration of MCT occurs

has been reported to be as high as 15% for translational optic flow (Edwards, et al., 1996). However, in another study that evaluated translational, radial and rotational optic flow the contrast level was found to be much lower, at about 2% to 4% (Allen, et al., 2010) .

Other factors that affect MCT include the number of dot elements, dot density, display size and dot motion duration. A study evaluating the interaction of these various factors reported that the number of elements present in the display was the more important factor, rather than the density of elements or the display size (Dakin, Mareschal, & Bex, 2005). Similarly, other studies have found that factors such as element density, size and exposure duration have little effect on motion sensitivity thresholds (Aaen-Stockdale, et al., 2007; Barlow & Tripathy, 1997; Bertone & Faubert, 2003; Scase, Braddick, & Raymond, 1996).

1.5 Clinical Implications of Motion Perception

Deficits in motion sensitivity indicate the presence of various underlying ocular and neurological disorders in children as well as adults. As motion is processed by a relatively well understood pathway of the neural system, the clinical implications of motion deficits have been explored extensively. Motion perception is affected by various disorders of childhood, such as amblyopia (Simmers, et al., 2003; Simmers, et al., 2006), dyslexia (Conlon, Sanders, & Wright, 2009; Ridder, Borsting, & Banton, 2001), autism (Annaz, et al., 2010; Spencer, et al., 2000) and low birth weight (MacKay et al., 2005). Motion perception is also affected in various adult disorders, such as Alzheimer's disease (G. C. Gilmore, Wenk, Naylor, & Koss, 1994; Rizzo & Nawrot, 1998), Parkinson's disease (Trick, Kaskie, & Steinman, 1994), lesions of the brain (Zihl, et al., 1983) and glaucoma (Falkenberg & Bex, 2007). Different tests based on motion sensitivity have been proposed for diagnosis, although these tests have been limited to testing in a laboratory setting. Tests based on motion sensitivity could be useful in the diagnosis of glaucoma (Babalola, 2005) and Alzheimer's disease (G. C. Gilmore, et al., 1994). Recently, a treatment modality for amblyopia has been proposed, based on motion stimuli and employing an anti-suppression mechanism (Hess, Mansouri, & Thompson, 2010). Motion perception analysis in people with these various disorders could lead to early detection and better management, thereby improving visual recovery.

1.6 Summary

Motion perception is an integral part of visual perception and involves structures from the retina to various parts of the brain with complex processing mechanisms. Optic flow is the motion type commonly experienced in daily life. Optic flow processing involves higher cortical neurons in processing global motion. Translational motion is processed in V1 and MT, while radial and rotational optic flow are processed in higher cortical areas, including MST. The visual system is also sensitive to speed and possibly uses different mechanisms and channels for detecting different speeds. The rate of development and maturation of various visual functions differs and complex visual functions that involve higher cortical areas are believed to mature later. Although several studies have evaluated the perception of translational patterns in children, very few have evaluated the development of complex optic flow perception.

The importance of defects in motion perception and the implications for various disorders is currently being explored. Better understanding of motion perception, its development and maturation could lead to exploration of motion related defects in various childhood as well as adult disorders.

1.7 Aims of the Study

Visual acuity is the visual function that is most commonly evaluated in a clinical setting. Other visual functions such as motion perception are not routinely evaluated. However, studies have shown that motion sensitivity is reduced in various childhood and adult disorders. The baseline data on the sensitivity and development of optic flow perception in children and adults are important for understanding the development of higher cortical functions. The information could also be useful for development of any diagnostic tool for the detection of various ocular and neurological disorders. With these perspectives in mind, we aimed to evaluate motion perception sensitivity, development and maturation in adults and children in Kathmandu.

The primary aim of this study was to evaluate the normal development and maturation of sensitivity to global motion perception in children in Kathmandu, Nepal. The secondary aims were to evaluate the effect of speed on the motion coherence threshold and to investigate differences between translational, radial and rotational motion coherence thresholds.

2.0 Methods and Methodology

This is a descriptive study completed in two phases. The first phase was a pilot study conducted in a laboratory setting. The pilot study was conducted to identify optimum stimulus parameters to be used in the main study. The second phase of the study was the main study, conducted in Kathmandu, Nepal.

2.1 Observers

2.1.1 Phase I (Pilot Study)

Four observers participated in the pilot study, including the author. The other three subjects were naive observers, oblivious to the objectives of the experiment. All observers had unaided or best corrected visual acuity of Log MAR 0.0. Informed consent was obtained from all observers before participation.

2.1.2 Phase II (Main Study)

For the main study, adults and children from the Kathmandu district of Nepal were evaluated for motion coherence threshold. Adult observers for this experiment were student volunteers from the Institute of Medicine, Tribhuvan University, Nepal. A total of 24 adults from 19 to 29 years of age (mean age, 23.66 years) with normal ocular and systemic health participated. All observers had visual acuity of log MAR 0.0 or better, either unaided or with best refractive correction. Consent was obtained after informing observers about the purpose of study.

Children from two schools were evaluated. Screening details are provided in Appendix 7.8. For children aged between eight and 16 years, a best corrected acuity of log MAR 0.0 was required for inclusion in the study. For children aged less than eight years a corrected acuity of 0.18 was acceptable. Children who could not complete the experiments were excluded from the study. The aim was to collect data from at least 10 children of each age between six and 16 years. However, only eight six-year-old children were capable of completing the evaluation. A total of 125 children between the ages of 6 and 16 years, from two schools, satisfied the inclusion

criteria after the screening procedure and were included in the study. School authorities and the children's guardians were informed of the aim of the study and its procedures. Informed consent was obtained from the children and their guardians. A detailed information sheet and consent form, describing the procedure of the study, its significance and effect on the participants was used for this purpose (Appendix 7.2, 7.3). Details of sampling, inclusion and exclusion criteria are provided in Appendix 7.6.

2.2 Apparatus and Stimuli

The apparatus used in the pilot study (Phase I) differed from that used in the main study (Phase II) but the stimuli and procedures were the same for both studies. The pilot study was conducted in a laboratory setting using 22 inch CRT monitor with a resolution of 32 bit and a refresh rate of 75Hz. Stimuli for the main study were displayed on a 15.4" Mac Book Pro laptop monitor from Apple^{TM} with 1440 by 900 pixels resolution. A standard computer keyboard was used to collect the participant's responses. The display units were calibrated with the help of Spyder^{TM} software before the start of each evaluation to obtain a uniform display output. The experimental stimulus used to evaluate MCT was programmed in the Matlab (MATLAB, 2009) using PsychToolBox software (Brainard, 1997; Pelli, 1997). The stimulus was a Random dot Kinematogram (RDK), consisting of a total of 100 black and white dots. The black and white dots were presented on a uniform gray background with mean luminance of 50cd/m^2. The visibility of the dots (Michelson's contrast) could be changed by increasing the luminance of dots with respect to the background.

Michelson contrast= $(L_{dots} - L_{background}) / (L_{dots} + L_{background})$

L_{dots} and $L_{background}$ are the luminance of dots and background respectively.

The stimulus was presented within a circular window at the centre of the display. The total diameter of the stimulus was 256 pixels, subtending an angle of eight degrees at a viewing distance of 57 cm. Each stimulus contained 100 non-overlapping dots of 0.188° (6 pixels) diameter, with dot density of ~two dots per degree squared. Each dot moved in a certain trajectory for three frames before disappearing and then reappearing at a different random location anywhere within the stimulus. The total duration of each image was 500 milliseconds. A

fixation dot with a diameter of 0.25° (8 pixels) was located at the centre of the display. A schematic representation of translation, radial and rotational stimuli is provided in Figure 2.
In each trial, the dots moved either coherently (signal dots) or in random directions (noise dots). Subjects had to respond with one of two alternative forced choice preferences (2AFC) to identify the perceived direction of signal dots. The alternative choices were: radial expansion or contraction, clockwise or anti-clockwise rotation and right or left translation.

MCT was obtained from 50 trials. The results were then fitted to a psychometric function using the functional adaptive sequential testing (FAST) method in Matlab. FAST is an efficient and effective method which relates different individual threshold measures from individual trials to produce a final threshold value (Vul, Bergsma, & MacLeod, 2010).

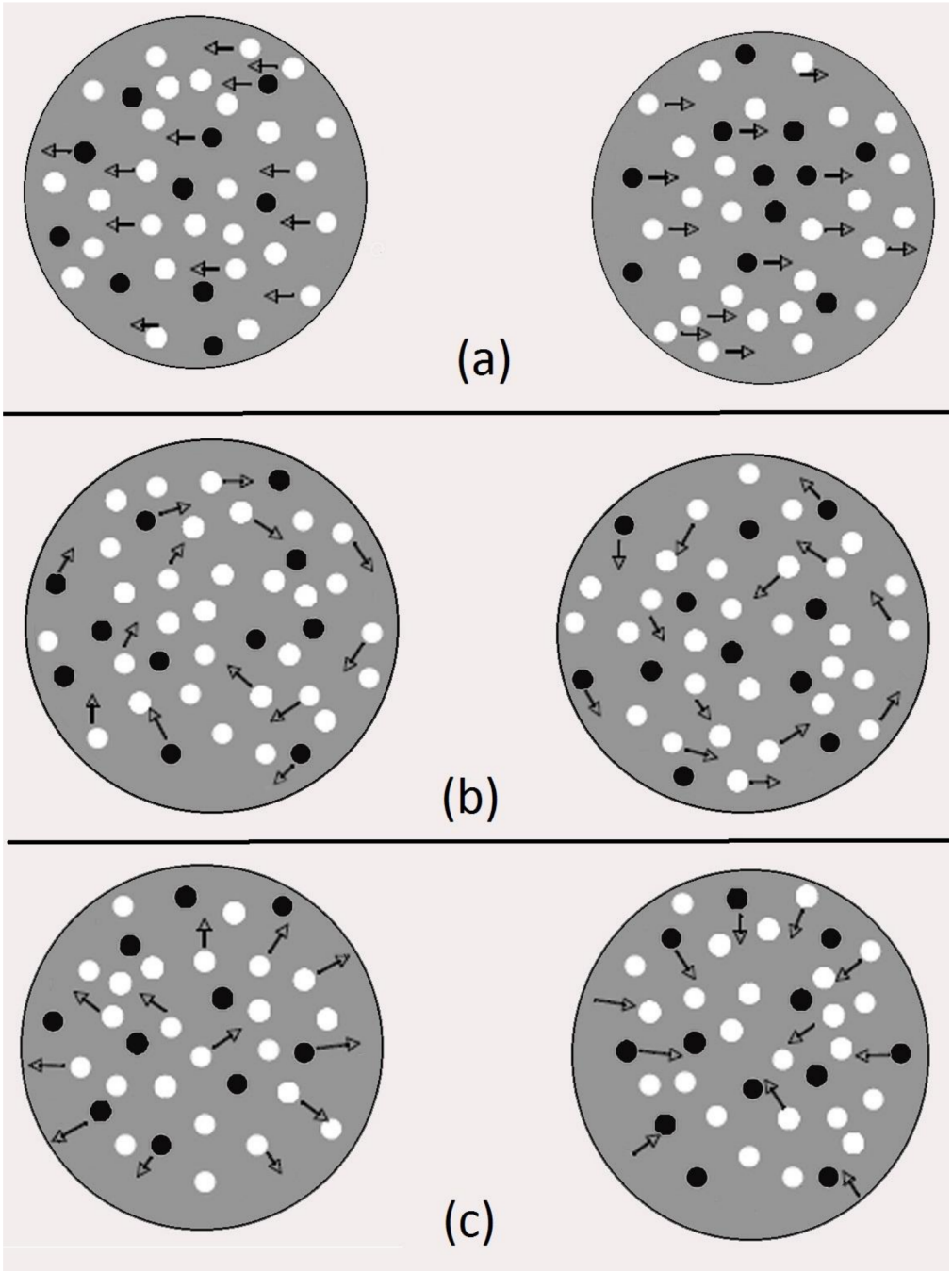

Figure 2: Schematic drawing of different optic flow patterns; (a) left and right translation, (b) clockwise and anti-clockwise rotation, and (c) radial expansion and contraction.

2.3 General Procedure

All observers underwent a general examination (Appendix 7.7) of visual acuity and ocular health. Only those with normal acuity and ocular health were included in the study. The Freiburg visual acuity test (Bach, 1996, 2007) was used to measure visual acuity and contrast sensitivity (Appendix 7.5).

The observer's task was to indicate whether the signal dots had moved to the left or right in translational motion, had rotated clockwise or anti-clockwise in rotational motion, or had contracted or expanded in radial motion. The observer was given immediate feedback by the fixation dot changing colour: red for an incorrect response and green for a correct response. Keyboard presses were used to collect the response. In children aged 10 years and younger, however, a verbal response was obtained; the investigator, who was blinded to the stimulus display, then pressed the appropriate key. This was necessary because the younger children were at times uncertain of which key to press for which response. A protocol of the procedure (Appendix 7.1) was developed to ensure that each observer was provided with the same information about the test before the start of the experiment. The test was conducted in a dark room in which the computer screen was the only source of light. The observer was required to fixate at the central fixation dot at all times during the trial.

After the observer was familiarised with the settings, a demonstration of each type of stimulus was presented. The demonstration version consisted of 15 trials which started with dots at a threshold of 75%; that is, 75 of the 100 dots moved in a coherent direction. This relatively high threshold made it easy for the observer to appreciate the movement of the stimulus. Demonstration trials were repeated twice to allow the observer to become familiar with the stimulus. If the observer could not complete the demonstration evaluation, they were excluded from further participation. After the demonstration trials, the final MCT test was initiated. Each observer completed two trials of experiments. The same stimuli and general procedures were used for all the experiments in this study.

2.4 Data Analysis

Demographic data were analysed using the Microsoft Excel spreadsheet application. MCT data were collected using Matlab software and later transferred manually to excel. After data collection, all personal information was coded to protect the privacy of the participants. Further analysis was conducted using only the coded information.

Statistical analyses were conducted using SPSS 17, Statplus and Microsoft Excel for Windows 7. Various statistical tests were used. The significance level for all statistical tests was set at 5%

($p<0.05$); Bonferroni correction of significance levels was conducted when necessary. The Wilcoxon matched pair test was used to analyse differences between thresholds from a single observer. Two-way analysis of variance (ANOVA) for independent samples was used to analyse data from multiple samples. Post-hoc tests were conducted using the Bonferroni mean test to avoid Type 1 error. Linear regression was used to analyse the pattern of development of MCT in children. Details of the statistical procedures used are provided in the relevant parts of the results section.

2.5 Ethical Considerations

The study followed the tenets of the Helsinki declaration for research and the research protocol (Appendix 7.9) and was reviewed and approved by the Nepal Health Research Council (Appendix 7.4). An information sheet was given to the relevant school authorities, adult participants and guardians of child participants before starting the study (Appendix 7.2). The information sheet included the aim and procedure of the experiment, along with details of potential advantages and disadvantages of participating in the study. It emphasised that participation was voluntary and that observers would be permitted to discontinue participation at any point in the study without having to state a reason (Appendix 7.3). Children were only included in the study after written consent had been obtained from both themselves and their guardians.

3.0 Results

Results are presented separately for the pilot study (part I) and the main study (Part II).

3.1 Pilot Study (Part I)

This experiment was carried out to determine the optimum speed and contrast parameters to be used in main study (Part II).

The Effect of Speed on the Motion Coherence Threshold

MCT was measured for translational, radial and rotational optic flow patterns at various dot speeds of 0.25, 0.5,1,2,3,4,5,6,7 pixels per frame. MCT was high for lower speeds before levelling off at 15-20% at higher speeds for all three optic flow patterns (Figure 3). For rotational and radial optic flow, MCT for dot speeds of <2 pixel/frame was higher than for dot speeds >2 pixel/frame (Figure 3a). For translational motion of <3 pixel/frame, MCT was higher than for dot speeds >3 pixel/frame (Figure 3a). Similar results were obtained for the author (Figure 3b) and a naive observer (Figure 3c).

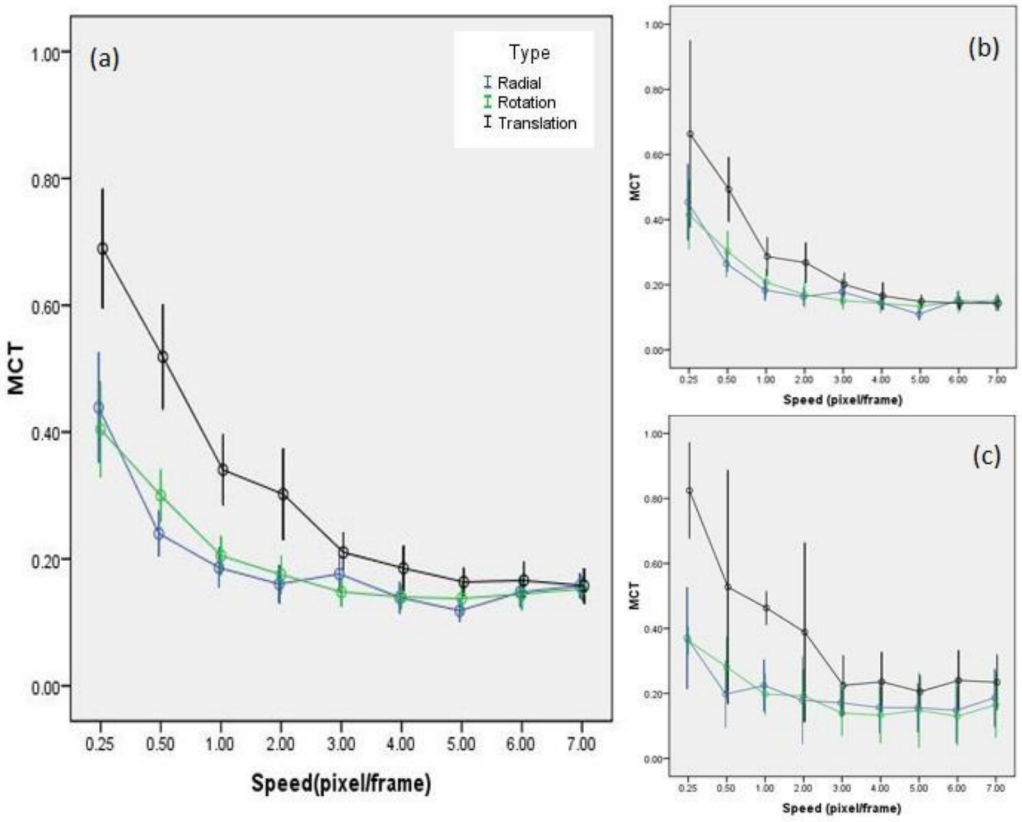

Figure 3: Mean motion coherence thresholds (proportion correct) at different speeds. (a) Mean MCT (n=4 subjects) for Translational, Radial and Rotational dot motion. (b) Mean MCT for the author. (c) Mean MCT for a naive observer. Error bars represent 95% confidence intervals.

Two-way ANOVA with motion type (translation, rotation or radial) and dot speed (from 0.25 to 7.00) as fixed factors revealed significant effects on MCT of both type [$F(2,393)=64.50$, $p<0.05$] and speed [$F(8,393)=101.92$, $p<0.05$]. The interaction between type and speed was also significant [$F(16,393)=7.43$, $p<0.05$].

Analysis of the dot speed factor with the Bonferroni test for differences between means revealed that MCT at speeds <1 pixel/frame was significantly different to MCT at speeds >2 pixel/frame ($p<0.0014$). There was no significant effect of speed on MCT at dot speeds >3 pixel/frame ($p>0.05$). The Bonferroni test for differences between means was also used to analyse the effect of speed for the different stimulus motion types. For translational motion, MCT for speeds of less than or equal to 2 pixel/frame significantly differed from MCT for higher speeds >2 pixel/frame ($p<0.0014$). For rotational and radial stimuli MCT at speeds less than 1 pixel/frame significantly differed from MCT at > 1 pixel/frame ($p<0.0014$).

Differences between the three stimulus types were also evaluated with the Bonferroni test for differences between means. At speeds of 2 pixel/frame and below, the translational threshold was higher than the radial and rotational thresholds ($p<0.0167$). There was no difference between the radial and rotational thresholds ($p>0.05$). At speeds of 3 to 7 pixel/frame, there was no significant difference between three stimuli ($p>0.05$).

The Effect of Contrast on the Motion Coherence Threshold

MCT was measured for translational, radial and rotational optic flow patterns at various contrast levels. Data were obtained from the author for all contrast levels, from 0.03, 0.05, 0.08, 0.10, 0.15, 0.20, 0.40, 0.50, 0.75 to 0.80 Michelson contrast. Results showed that at 0.03 contrast MCT was very high, with large confidence intervals. Attempts were made to evaluate MCT for other participants at all contrast levels; however, none could complete the evaluation at 0.03 and hence they were evaluated for contrast levels of 0.05 to 0.80.

MCT for all three optic flow stimuli was low for a wide range of contrast levels. Increases in MCT were only observed below a contrast of 0.08 at speeds of 6 pixel/frame (Figure 4) and 3 pixels/frame (Figure 5). The pattern was similar for the author and the naive observers.

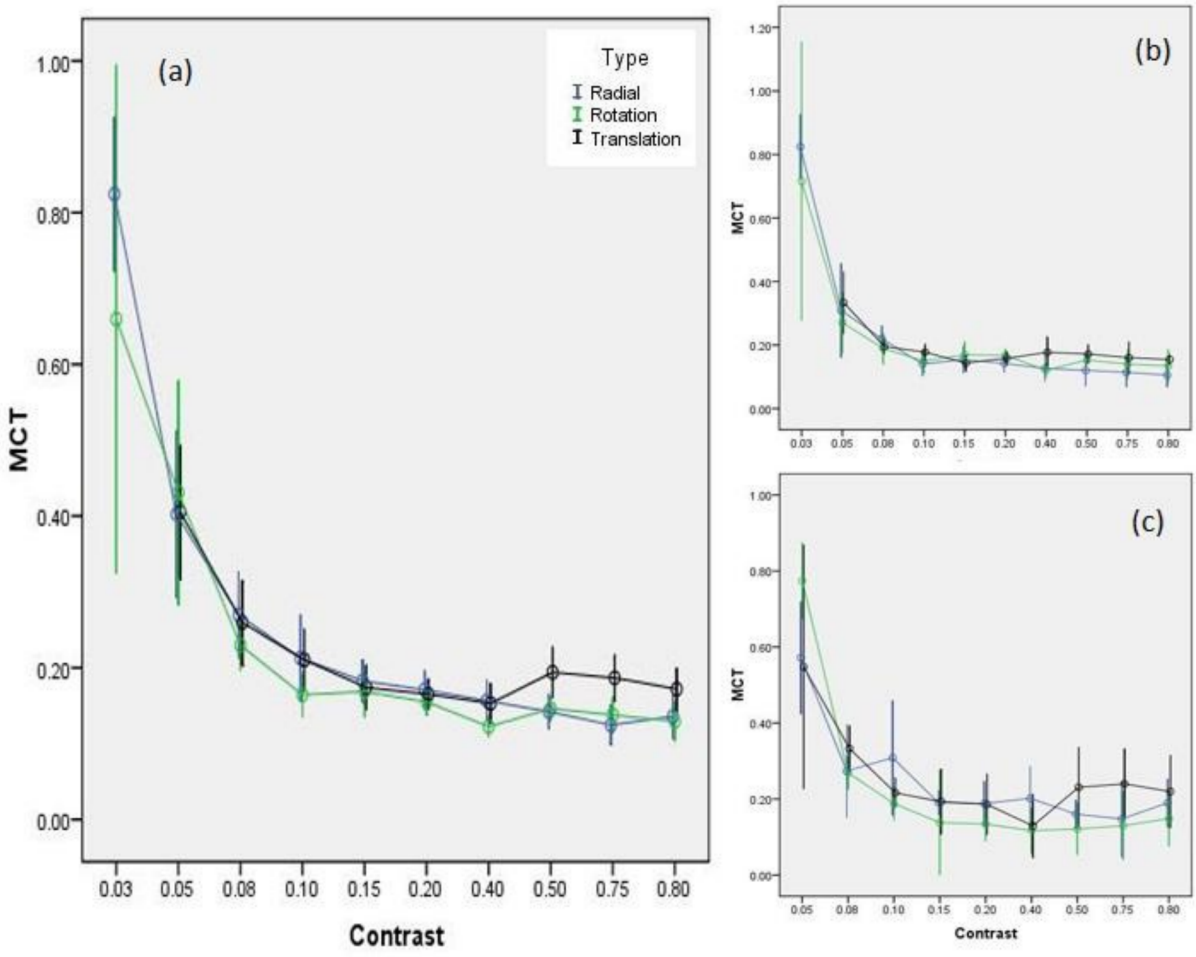

Figure 4: Mean motion coherence thresholds (proportion correct) at different contrast levels at a speed of 6 pixel/frame. (a) Mean MCT (n=4 subjects) for Translational, Radial and Rotational motion. (b) Mean MCT for the author. (c) Mean MCT for a naive observer. Error bars represent 95% confidence intervals.

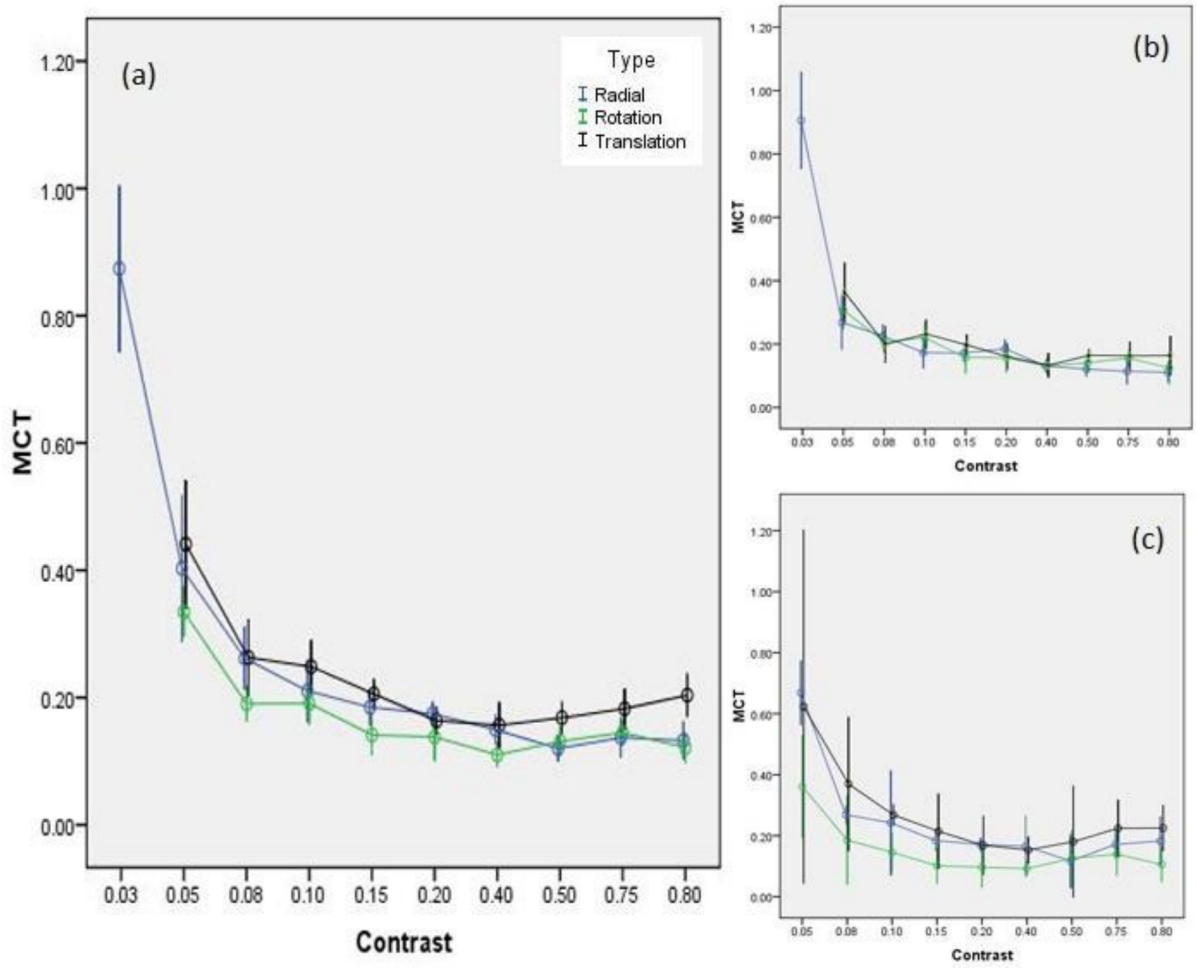

Figure 5: Mean motion coherence thresholds (proportion correct) at different contrast levels at a speed of 3 pixel/frame. (a) Mean MCT (n=4 subjects) for Translational, Radial and Rotational motion. (b) Mean MCT for the author. (c) Mean MCT for a naive observer. Error bars represent 95% confidence intervals.

Two-way ANOVA with contrast level and type of motion as fixed factors revealed a significant effect of contrast level at dot speeds of 6 pixel/frame [$F(9,332)=77.64$, $p<0.05$] and 3 pixel/frame [$F(9,327)=64.51$, $p<0.05$], but no effect of motion type ($p>0.05$). The interaction between contrast level and motion type was significant at dot speeds of 3 pixel/frame [$F(18,327)=3.432$, $p<0.05$] but not at speeds of 6 pixel/frame ($p>0.05$).

Comparing contrast levels with the Bonefferri mean test revealed that MCT at a contrast level of 0.05 was significantly different to MCT at levels of contrast of 0.08 and above at speed 3 pixel/frame ($p<0.0011$). Similarly MCT at a contrast level of 0.08 was significantly different to MCT at levels of contrast of 0.1 and above at speed 6 pixel/frame ($p<0.0011$).This was true for all three optic flow patterns. Comparing the three optic flow patterns at different contrast levels

revealed no significant difference between the translational, rotational and radial patterns ($p>0.05$) at contrast levels of 0.05 and higher.

Results obtained from the pilot study provided the basis for the selection of parameters used in the main experiment. The results are discussed in detail on chapter 4.0, the Discussion with regards to effect of speed, type and contrast. We are summarising the major findings that were used for main study (part II) of the study. Two dot speeds, 2 and 7 pixel/frame (1.56°/s and 5.48°/s) were selected for further evaluation. They represented a relatively slow and a relatively fast speed, respectively. Other studies have employed similar speeds to represent relatively slow (Khuu & Badcock, 2002; Lee & Lu, 2010) and fast (Aaen-Stockdale, et al., 2007; Allen, et al., 2010; Edwards & Badcock, 1995; Simmers, et al., 2006) motion stimuli. From the experiment on contrast, a 75% Michelson contrast was selected. MCT was high only for the lowest contrast, beyond that different contrast levels had no effect. To ensure that the stimulus was easily visible, a contrast level of 75% was selected for further experiments. These parameters of speed and contrast were selected so that naive observers participating in the main experiment could easily observe the stimulus.

The aims of the pilot study were to determine the optimum parameters of speed and contrast to use in the main experiment and to investigate how these would affect MCT for different types of optic flow patterns. The pilot study also familiarised the investigator with the stimuli and provided valuable experience before the main study was conducted in a community setting in Nepal. The better understanding of stimulus helped the investigator to explain what was expected of observers during the experiment. In addition, analysing the data from the pilot study helped to ensure that the most appropriate statistical tests were used to test the hypothesis of the main study.

3.2 Main Study (Part II)

In the main Study, MCT was evaluated in both adults and children. The aim of the experiment was to evaluate the development and maturation of global motion processing in children. Adult data were collected to provide a comparison with the children's data. The aim was to collect MCT data for all three optic flow types for both adults and children. However, this was not

possible for the children. Time was the main constraint: children required more time and more periods of rest to complete the test, as they could not concentrate for as long as the adults. Hence, only radial stimuli were used to test the majority of children. However, a small subset of children (aged 8, 12 and 16 years) was also evaluated using translational motion.

3.2.1 Motion Coherence Threshold in Adults

MCT was evaluated for adult participants for all three optic flow patterns at two dots speeds. MCT for the relatively slow speed (2 pixel/frame, 1.56°/s) and relatively fast speed (7pixel/frame, 5.48°/s) were different for all three optic flow patterns (Figure 6). Mean MCT (with 95% confidence interval) at the slower speed was lowest for radial optic flow (0.288 +/-0.065) and highest for translational motion (0.41 +/-0.089). Similarly, at the faster speed mean MCT was highest for translational motion (0.211 +/-0.035) and lowest for rotational motion (0.17 +/-0.021). The confidence interval for the slower speed was larger than for the faster speed (Figure 6).

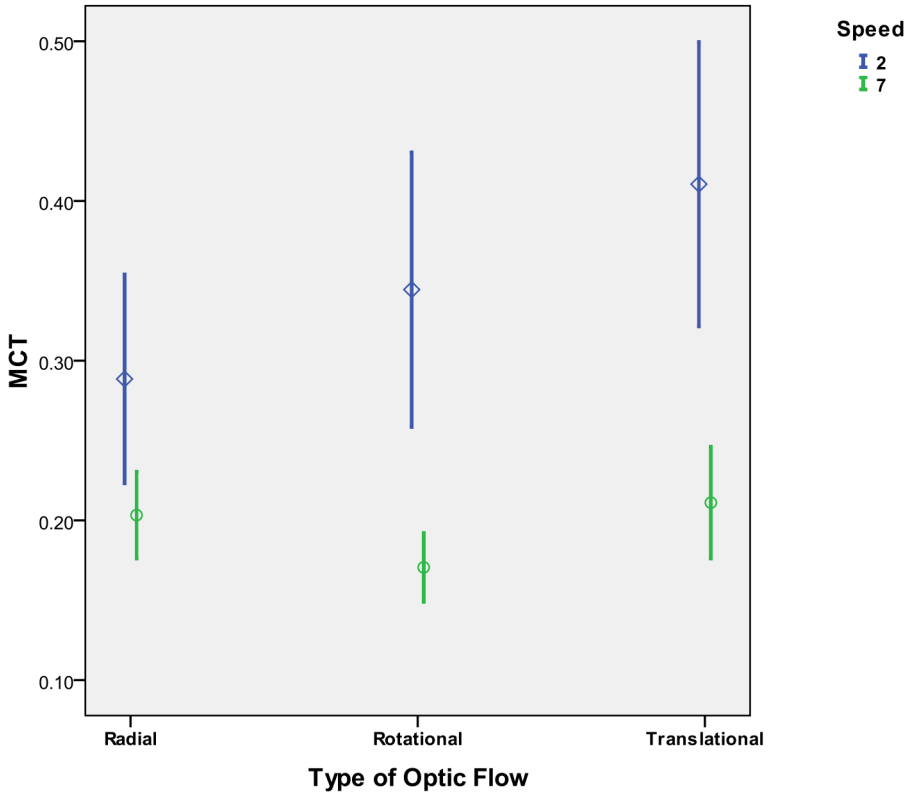

Figure 6: Mean adult Motion coherence thresholds (proportion correct) for three optic flow types at two speeds (n=24). Error bars represent 95% confidence intervals.

Two-way ANOVA was used to analyse the effect of speed and optic flow pattern on the coherence threshold. There was a significant effect of speed [$F(1,138) = 40.9$, $p < 0.05$] but no effect of type of optic flow pattern and no interaction between speed and type of optic flow pattern ($p > 0.05$). The Bonferroni test for differences between means showed that for all three optic flow types there was significant decrease in MCT for the higher speed compared with the lower speed ($p < 0.05$).

At the slower speed, there was a significant difference between radial and translational stimuli ($p < 0.0167$) with the Bonferroni test for differences between means. However, no differences were observed between the other stimulus types: translational vs. rotational and radial vs. rotational. At the higher speed, no significant difference in threshold was observed between the three motion types ($p > 0.05$).

3.2.2 Development of the Motion Coherence Threshold in Children

A total of 125 children were evaluated using radial stimuli at two speeds (2 and 7 pixel/frame). Four children (three aged six years and one aged 14 years) were excluded from further analysis as they recorded thresholds of more than 100%. Data from 119 children, 60 male and 59 female, were thus analysed.

The results showed that MCT steadily improved from age six to age 16 years (Figure 7). Mean MCT was relatively high for the lower age group, but improved (i.e. became lower) with age. Confidence intervals were larger for the younger children (Figure 7). However, even for the 16-year–old children, MCT was higher than for the adults. Mean MCT was consistently different for the two dot speeds across the whole age range.

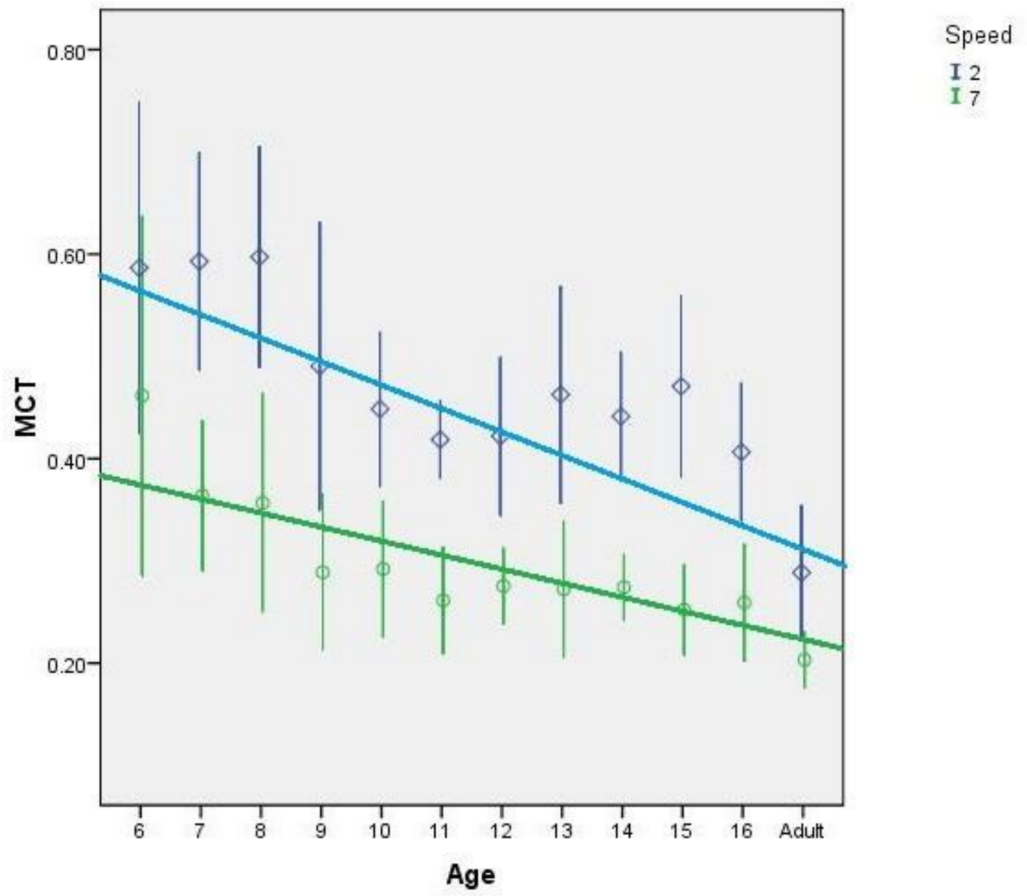

Figure 7: Mean radial motion coherence thresholds (proportion correct) at different ages for two dot speeds. The green and blue lines are linear regression lines; Error bars represent 95% confidence intervals.

Linear regression was used to analyse the difference in MCT across the age range (including the adults). Separate linear regression was performed for the two speeds. The regression analysis showed a reliable improvement in MCT with age for both the lower [$F(1,141) = 51.26$, $p<0.05$, $R^2=0.267$] and higher [$F(1,141) = 37.59$, $p<0.05$, $R^2=0.21$] speeds. There was a significant difference ($p<0.05$) in the slope of the regression lines at the two speeds (Figure 7), suggesting a difference in development pattern.

MCT was lower at the higher speed for all ages (Figure 7). This difference was significant ($p<0.05$) with Wilcoxcon matched paired test at all ages except six years. Mean MCT at each age, for both speeds, together with corresponding p values, is shown in Table 1.

Table 1: Mean radial motion coherence thresholds for children of different ages and adults

		Dot speed		
Age(years)	**N**	**2 pixel/frame**	**7 pixel/frame**	**P Value**
6	5	0.5867	0.4824	0.500
7	13	0.5930	0.3640	0.005
8	10	0.5972	0.3656	0.005
9	12	0.4906	0.2799	0.008
10	12	0.4486	0.2921	0.006
11	11	0.4186	0.2615	0.003
12	12	0.4220	0.2755	0.003
13	11	0.4627	0.2723	0.003
14	9	0.4414	0.2742	0.008
15	11	0.4708	0.2523	0.003
16	13	0.4064	0.2592	0.004
Adult	24	0.2885	0.2033	0.041

We evaluated the relative immaturity of MCT in children of age 6 and 16 years in comparisons to adult level. This was done by calculating the ratio of mean MCT of children divided by adult value. As Figure 8 shows children at both 6 and 16 years, are immature for radial MCT as compared to adults (the value of one represents the adult MCT). Six years old are more than two times immature than adult at both speed while 16 years are around 1.4 times immature than adults.

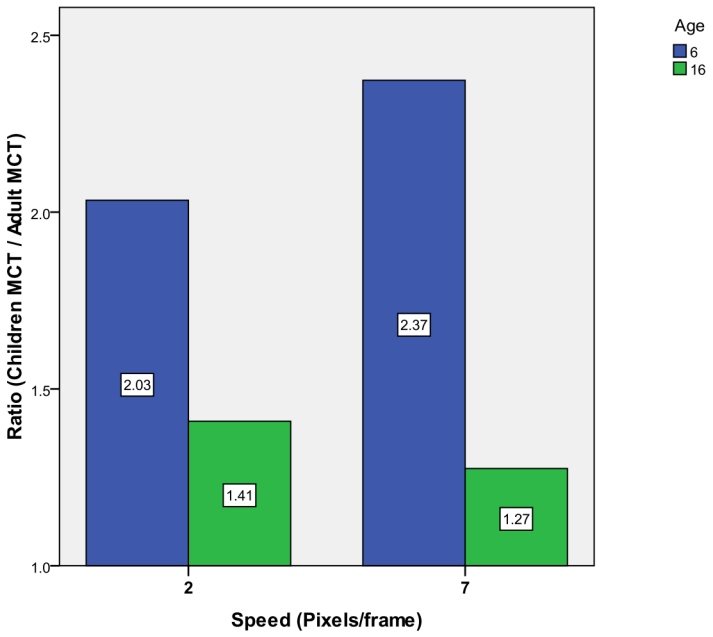

Figure 8: Ratio of children/Adult motion coherence threshold. Plot shows ratio of children and adult MCT at two speeds.

The Development of Translation Motion Coherence Threshold

A subset of children (aged 8, 12 and 16 years) were also tested for translational MCT at speeds of 2 and 7 pixel/frame. Ten eight-year-old children were evaluated, but data from only seven children were analysed as three produced erroneous data (thresholds higher than 100%).

Figure 9 shows mean translational MCT at the different ages and speeds. Mean MCT at 2 pixel/frame and 7 pixel/frame for children of 8,12 and 16 years are similar to adult MCT. Linear regression carried out on combined data from the children and adults at both speeds showed no significant differences ($p>0.05$).

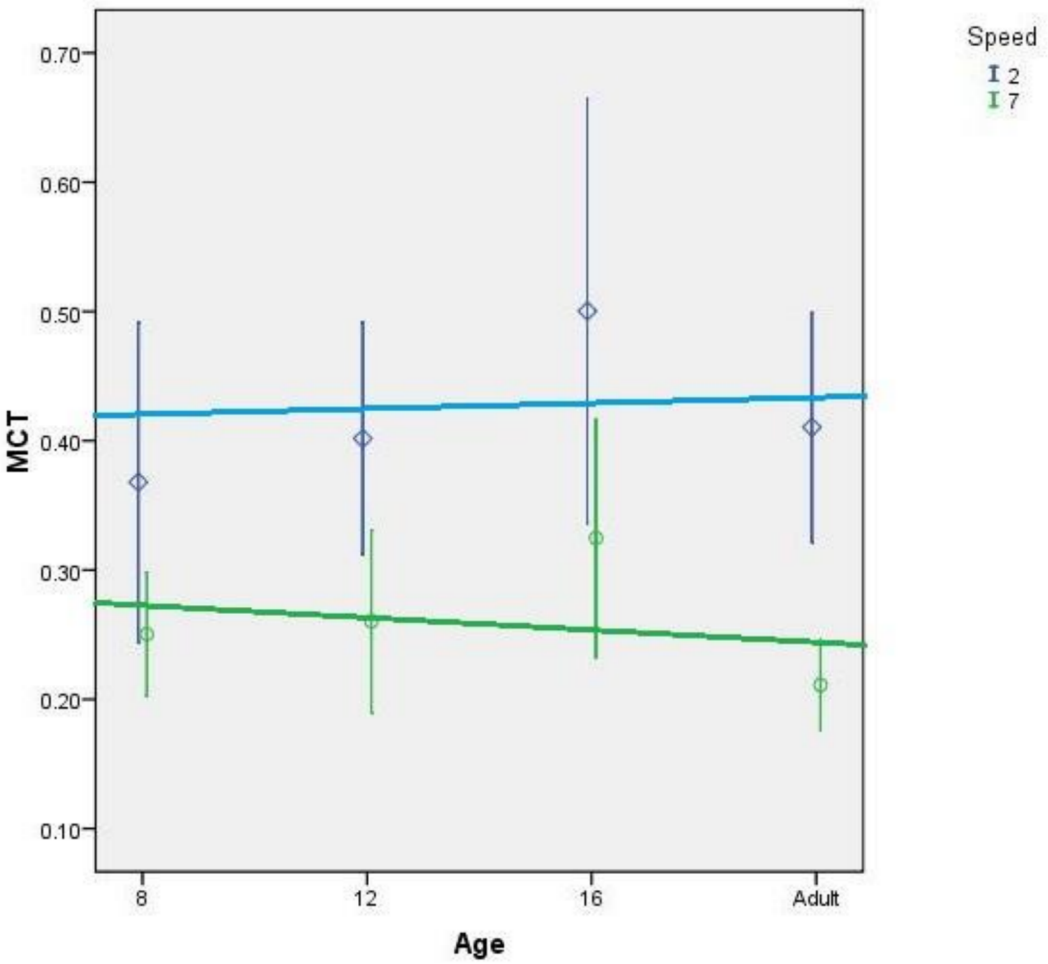

Figure 9: Mean translational motion coherence thresholds (proportion correct) at different ages at two speeds. The green and blue lines are linear regression lines and error bars represent 95% confidence intervals.

Mean translational MCT differed at the two speeds (Figure 9). As for the radial MCT, the threshold for translation was better (lower) at the higher speed ($p < 0.05$) with Wilcoxcon matched paired test. Mean translational MCT at each age, for both speeds, together with corresponding p value, is shown in Table 2.

Table 2: Mean translational motion coherence thresholds for children of 8, 12 and 16 years and adults.

		Dot speed		
Age (years)	**N**	**2 pixel/frame**	**7 pixel/frame**	**p value**
8	7	0.3680	0.2503	0.0425
12	11	0.4018	0.2604	0.0044
16	10	0.5003	0.3247	0.0069
Adult	24	0.4105	0.2111	0.0000

Translational MCT and radial MCT were compared for the same observers. As can be seen from the regression lines in Figure 10, development of MCT for translation and radial optic flow is different. The development of MCT for translation seems to mature at 8 years but for radial MCT there is clear pattern of development through 8,12 and 16 years. MCT for translation and radial optic flow also showed no significant difference with Wilcoxcon match pair test for different age (p value>0.05) except for age 8 at speed 2 (Table 3).

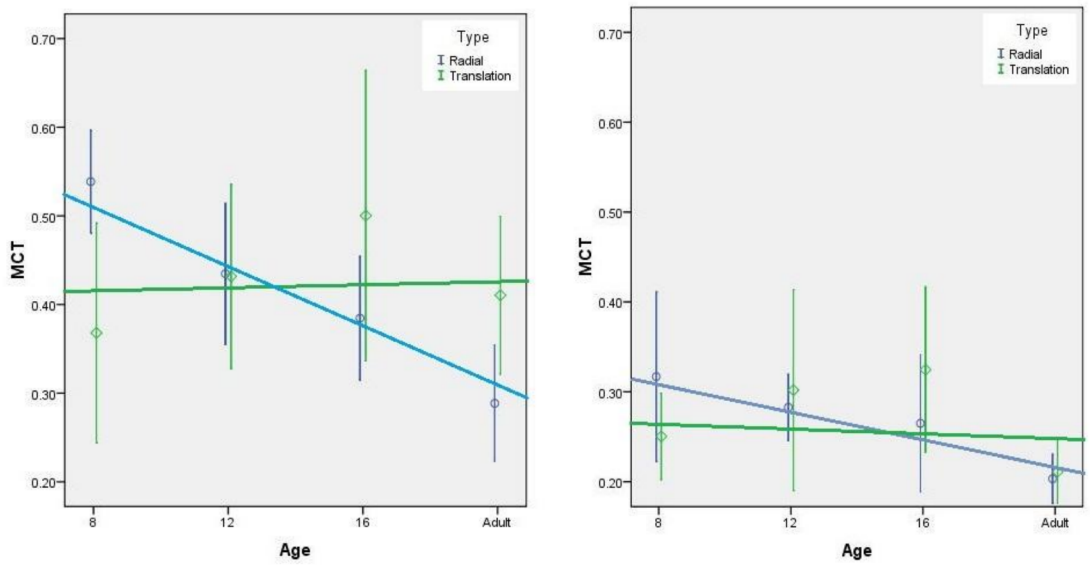

Figure 10: Mean radial and translational motion coherence thresholds (proportion correct) at 2 pixel/frame (a) and 7 pixel/frame (b) for adults and the subgroup of children. The green and blue lines are linear regression lines and error bars represent 95% confidence intervals.

Table 3: Mean translational and radial motion coherence thresholds for the subset of children aged 8, 12 and 16 years and adults.

Age (years)	N	Dot speed=2 pixel/frame			Dot speed=7 pixel/frame		
		Radial MCT	Translational MCT	p Value	Radial MCT	Translational MCT	p Value
8	7	0.5387	0.3680	0.028	0.3169	0.2503	0.1763
12	11	0.4278	0.4018	0.9292	0.2820	0.2604	0.7897
16	10	0.3846	0.5004	0.3863	0.2649	0.3247	0.2845
Adult	24	0.2885	0.4105	0.0113	0.2033	0.2111	1

4.0 Discussion

This study investigated the development and maturation of sensitivity to different optic flow patterns in children. Adults were also evaluated and acted as a reference group. The results of the pilot study and main study are discussed here.

4.1 The Development and Maturation of the Motion Coherence Threshold

This section will discuss the data collected from children with regards to development and maturation. In this study, MCT for radial motion at both relatively slow (2pixel/frame, 1.56°/s) and relatively fast (7pixel/frame, 5.48°/s) speeds showed reliable improvement with increasing age; however, even for the 16-year-old subjects, MCT did not reach the adult level. The improvement in MCT is indicative of the continual development of sensitivity to radial optic flow throughout childhood. Moreover, younger children had worse (higher) MCT than older children and adults for the radial optic flow pattern. Translational MCT did not show a statistically significant difference between children (aged 8, 12 or 16 years) and adults. Greater sensitivity at the higher speed was found in all age groups for both radial and translational MCT. Greater sensitivity persisted for the higher speed regardless of age. A different pattern of development was observed for radial MCT at the two speeds. MCT for the higher speed was closer to the adult level than for the lower speed. The effect of speed is discussed further in the next Chapter of the Discussion, 4.2 The Effect of Speed.

In this study younger children had lower sensitivity to optic flow patterns than older children and adults. Several other studies have reported immaturity of MCT in young children for different motion functions. For example, Ellemberg et al (2004) evaluated translational global motion in 5–year-old children using a random gabor kinematogram and found immaturity of MCT, compared with adults, at speeds of 1.5°/s, 6°/s and 9°/s. Similarly, Ahmed et al (2005) reported that five -year-olds have immaturity, compared with adults, in detecting local motion at speeds of 1.5°/s and 6.0°/s. In the current study, we also found that younger children were worse than older children and adults at detecting radial optic flow at speeds of 1.56°/s and 5.6 °/s.

The current study showed that sensitivity to radial optic flow develops with age, but even the 16-year-old children were immature compared with adults, at both dot speeds. To the best of

our knowledge, no other study has evaluated the development of the radial motion coherence threshold in children. However, studies on infants have reported steady improvement in the early years. Shirai et al (2008) have suggested that infants are able to discriminate between translational and radial patterns by the age of three months. In a similar study, sensitivity to radial optic flow improved steadily from the age of 2 to 8 months, with significant improvement occurring by 8 months (Brosseau-Lachaine, et al., 2008). Our study also shows improvement in radial MCT in children of various ages; however, development seems to follow a long path that continues into late childhood. One reasons for this prolonged development could be the nature of the higher cortical areas involved in motion processing. This is discussed further in relation to the development of radial and translational MCT later in this Chapter.

In the current study there was no statistical difference in translational MCT between children of different ages (8, 12 or 16 years) and adults, at both speeds. Several studies have investigated the development of translational coherence in children aged from 3 to 11 years. Annaz et al (2010) reported an improvement in translational MCT for children aged from 5 to 11.5 years, but did not compare these with adult subjects. In another study evaluating global translational motion (Parrish, et al., 2005) there was no statistical difference in sensitivity in children (from age 3 to 12 years) and adults. However, MCT was higher for children aged 3 to 6 years than for the group of 7 to 8 years or higher, implying maturation at 7 to 8 years. In our study also we found no difference in translational MCT for children aged 8 years and higher and adults. However other studies (Gunn, et al., 2002; Spencer, et al., 2000) have reported maturation at the slightly higher age of 10 to 11 years. There are fundamental differences in the stimuli and procedure used to measure MCT in the present study and previous studies (Annaz, et al., 2010; Gunn, et al., 2002; Spencer, et al., 2000). The stimulus used in these other studies had two rectangular RDK displays with white elements on a black background. Dot lifetime was 6 frames (compared to 3 frames in our study) and dot speed was 6°/s, similar to the higher speed in our study. The observer's task in these previous studies was to choose the part of the display in which motion was coherent in a certain direction, thereby evaluating localisation of coherent motion within the stimulus. In the current study, however, the signal and noise elements were displayed in same area of the stimulus and the observer's task was to discriminate the change of direction of the optic flow pattern (for example, a change from right to left translation); hence,

our procedure was concerned with direction discrimination. Such differences in stimuli and experimental procedure could account for the difference in age of maturation of translational MCT found in the current and previous studies.

Our results suggest that translational MCT matures earlier than radial MCT. Detecting radial flow is a more complex task than detecting translational flow and involves a higher level of visual cortex processing (in the MST area) than translational flow (which involves the MT area). Various studies have suggested that visual functions that require higher cortical processing mature later than those that require lower levels of processing (Ellemberg, et al., 2004; Ellemberg et al., 2003; R. O. Gilmore, et al., 2007; Kovacs, et al., 1999; Schrauf, et al., 1999). To our knowledge, there are no behavioural studies comparing the development of translational and radial optic flow in children. Ellemberg et al (2004, 2005) evaluated local and global translational motion in 5-year-old children and reported that global translational motion processing (which is attributed to MT) is more immature in 5–year-olds than local motion processing (which occurs at a lower processing level, in area V1 of the visual cortex). Support for the notion of late maturation of visual functions that require higher cortical processing has come from a study in which visual evoked potential (VEP) responses to various optic flow patterns were observed in infants and adults (R. O. Gilmore, et al., 2007). Reliable VEP responses were elicited in infants by translational patterns, but not by radial or rotational patterns. However, in adults there was a stronger response to radial motion than to translational motion. This suggests that the motion processing system which detects translational flow develops earlier than systems that are concerned with detecting complex optic flow patterns. Differences between translational and radial motion detection are also apparent in old age, with MCT for translational flow showing a faster decline than MCT for radial flow (Billino, et al., 2008).

Other visual functions involving higher visual cortical areas have also been reported to mature later than those involving lower processing areas. For example, dynamic visual acuity has been studied using an RDK in which dots that made up a Landolt's C moved with a different motion coherence level than background dots (Schrauf, et al., 1999). The observer's task was to indentify the gap in the stimulus that was defined by the difference in motion contrast of the dots

and the background. This study reported a long developmental curve for maturation, with performance reaching adult levels only at the age of 15 years. It was suggested that this delayed maturation might be due to the relative immaturity of area MT, which is involved in the processing of such stimuli, compared with V1, which is believed to process luminance-based contrast acuity. Another study used a spatial integration task to investigate the ventral visual system (Kovacs, et al., 1999). Using a gabor pattern, the spatial integration task required integration of local visual features to provide a coherent scene. Improvement on the task was reported up until the age of 14 years. In the current study, MCT matured later for radial than translational optic flow. Radial optic flow is processed at a higher level of the visual cortex which integrates input from lower cortical areas. The results suggest that the system which processes the local features at lower cortical areas matures earlier than those higher functions that require the integration of input from these lower-level processing areas.

MCT has been evaluated in subjects with various childhood disorders in order to evaluate the integrity of the higher cortical level of the dorsal stream. Abnormalities in translational MCT have been reported as evidence of dorsal system deficits in disorders such as amblyopia (Simmers, et al., 2003), autism (Spencer, et al., 2000), dyslexia (Ridder, et al., 2001) and Williams' syndrome (Atkinson et al., 1997). In amblyopia, radial and rotational MCT are both defective, implying the involvement of higher extra cortical structure (Simmers, et al., 2006). Our results suggest that sensitivity to translational optical flow matures earlier than sensitivity to radial optic flow. The results of the current study show that detection of radial optic flow follows a long developmental process, continuing into late childhood and suggests that the higher motion system may be vulnerable even during late childhood. Even children as young as 6 years could discriminate the complex radial optic flow pattern. Our results raise the possibility of evaluating higher cortical areas in different childhood disorders using stimuli based on radial optic flow patterns. However, radial MCT values obtained from children should be compared with normal age matched control group rather than adults as the MCT of normal children are not at adult level.

4.2 The Effect of Stimulus Speed

The effect of dot speed was evaluated for different optic flow types in various experiments. In the pilot study, MCT was similar for a wide range of speeds (1.56°/s to 5.48°/s) but increased significantly at lower speeds (0.196°/s to 0.775°/s) for all three optic flow patterns. From the pilot study two speeds, one relatively slow and one relatively fast, were selected for further evaluation. The selection of these speeds was influenced by previous studies that had used similar speeds for the evaluation of optic flow (Aaen-Stockdale, et al., 2007; Allen, et al., 2010; Khuu & Badcock, 2002; Lee & Lu, 2010; Simmers, et al., 2003). Some studies have also reported the presence of different channels for processing slow and fast speeds (Edwards, et al., 1998; Khuu & Badcock, 2002). In our main study, evaluation of MCT in adults and children was performed using speeds of 1.56°/s and 5.48°/s. Adult MCT values were significantly higher for the lower speed than for the higher speed for translational, radial and rotational optic flow patterns. In both the children, MCT for translational and radial patterns was lower for the higher speed. These results confirm that speed has a significant effect on MCT, showing that the visual system is more sensitive to higher speeds than lower speeds. The effect of speed was also seen in the development of radial MCT in children aged from 6 to 16 years. The results suggested immaturity in the younger children regarding radial MCT, at both speeds, with continued improvement throughout childhood. However, the rate of development was different at the two speeds, with MCT closer to the adult level for the higher speed than for the lower speed.

Our finding regarding variation in MCT, with higher thresholds for lower speeds, is similar to findings from other studies that have evaluated local and global motion in children and adults. Snowden and Kavanagh (2006) evaluated the effect of aging on translational MCT using an RDK. They reported higher thresholds at a stimulus speed of 0.5°/s than at speeds of 1°/s and 2°/s for young adults as well as older observers. In another study (Ellemberg, et al., 2004) the threshold for global translational motion for 5-year–old children and adults was higher at speeds of 1.5°/s than at speeds of 6°/s and 9°/s. Similarly, Ahmed et al (2005) found that the threshold for local motion was higher at a lower speed (1.5°/s) than at higher speeds (6°/s and 12°/s) for both adults and children. In a fourth study, evaluation of local motion processing in children

aged 3 to 10 years revealed a lower threshold for faster (6Hz) than slower (1.5 Hz) motion at all ages (Armstrong, et al., 2009). Ahmed et al (2005) suggested that greater sensitivity to faster speeds for translational motion stimuli could be due to higher cortical cells in area MT being tuned to faster speeds. We also found higher sensitivity to faster motion for radial and rotational, as well as translational, motion patterns. The notion of greater sensitivity to higher speeds for complex motion is also supported by neuro-physiological evidence that area MST contains a high proportion of neurons tuned to faster speeds (Duffy & Wurtz, 1991).

The difference between fast and slow speeds is not only present during the evaluation of threshold but the effect is also seen in the development and maturation of global and local motion. The immaturity of children to slow speeds (compared with fast) has been reported in previous studies. Ellemberg et al (2004) reported that perception of global translational motion for 5-year-olds is more immature at 1.5°/s than at 6°/s and 9°/s. Greater immaturity for five-year-olds at lower speeds (1.5°/s) than at higher speeds (6°/s) has also been reported for local motion detection (Ahmed, et al., 2005). In the current study, the difference between radial MCT for younger children and adults was greater for the lower speed than for the higher speed, implying that children mature at different rates for fast and slow motion.

We also observed a difference in development of radial MCT at the two speeds, with the MCT at higher speed being closer to adult levels than the lower speed. Other motion-based visual functions such as motion-defined form perception have also been reported to develop differently for fast and slow speeds. Hayward et al (2011) evaluated the effect of speed on the development of motion-defined form perception at 0.1°/s, 0.9°/s and 5°/s. They used a stimulus in which a rectangular shape could be detected due to differences in the direction of signal motion in the rectangle and the surrounding area. Evaluation at various ages showed that the function matured earlier for relatively fast speeds compared with relatively slow or medium speeds. The implication of this developmental effect was also seen in the adult amblyopic population, with greater loss of function at slower speeds than faster speeds. In our study, we also found that radial motion perception develops at a different rate for slower and faster motion. These findings suggest that there are different channels of development for motion perception at slower and faster speeds.

Our findings of a difference in sensitivity to faster and slower speeds in children and adults, as well as a different pattern of development for radial optic flow perception at these speeds, supports the idea of separate mechanisms for perceiving slower and faster speeds. Evidence for separate processing channels for faster and slower motion has come from various electrophysiological (Heinrich, et al., 2004; Lorteije, et al., 2008) and behavioural (Edwards, et al., 1998; Khuu & Badcock, 2002) studies. In the electrophysiological studies (Heinrich, et al., 2004; Lorteije, et al., 2008) VEP responses to horizontal translation motion of 3.5°/s and 32°/s were recorded. The results showed that the slower and faster motion stimulated different cortical areas, indicating independent channels for processing. Several behavioural studies have also provided evidence for such a mechanism for translational, radial and rotational patterns (Edwards, et al., 1998; Khuu & Badcock, 2002). These studies have explored the notion of the existence of separate motion channels by evaluating the effect of relatively slow speed noise elements on faster signals, and vice versa. Edwards et al (1998) evaluated horizontal translational motion and reported that when the signal dots moved at 1.2°/s the addition of static noise dots or dots moving at greater than 4.8°/s had no effect on detection. In addition, noise dots moving at 1.2°/s did not affect signal dots moving at 10.8°/s as much as high-speed noise dots did. A similar study on radial and rotational optic flow patterns (Khuu & Badcock, 2002) evaluated signal speeds of 1.2°/s and 9.6°/s and reported that only the lower speed noise dots affected detection of the lower signal speed and only higher speed noise dots affected detection of the higher signal speed. This suggests that different motion channels exist for these different speeds. Our finding of a significant difference in MCT at two speeds for adults and children, together with a different pattern of development for radial optic flow at these speeds, is consistent with the idea of two different processing systems. The slower speed in our study is similar to that used in these other studies (Edwards, et al., 1998; Khuu & Badcock, 2002)and our results support the idea of separate processing channels. The faster speed (5.48°/s) is lower than used in other studies, but as reported in the study on horizontal translation (Edwards, et al., 1998), speeds higher than 4.8°/s seem to be processed by a different channel. However, these previous studies evaluated only two signal speeds that were very different to each other. They did not comment on what would be expected at intermediate speeds. Would each intermediate speed have its own channel? A more recent study with similar methods evaluated four different signal speeds (1.1°/s, 2.1°/s,5.1°/s and 10.6 °/s) with variable

noise dots (van Boxtel & Erkelens, 2006). This study reported relative overlapping of processing at different speeds, which suggests a single channel tuned for various speeds with different sensitivity at slower and faster speeds. This study evaluated speeds of 1.1°/s and 5.1°/s, which are similar to the speeds used in our study. In the processing model proposed by van Boxtel and Erkelens (2006), there was little overlap between these two speeds, however the intermediate speed of 2.1°/s showed considerable overlap with both speeds. This suggests that a single motion processing mechanism with neurones covering each part of the speed domain is adequate to explain the findings at the two different speeds in our study. The effect of different speeds in different experiments with adults, and the development in children might suggest support for the two motion theory. However, the theory of a single motion system tuned to different speeds with components serving faster speeds with better sensitivity seems equally plausible.

4.3 The Effect of Different Optic Flow Patterns

The effect of optic flow type on MCT was observed in both the pilot study and the main study. In the pilot study, MCT for translational, radial and rotational stimuli was similar for a wide range of speeds and contrasts. At the lower speeds, translational MCT was higher than either radial or rotational MCT. In the main study, adult MCT for translational flow was higher than for radial flow at a dot speed of 1.56°/s. Thresholds for radial and rotational flow did not show any statistical difference at either speed. For children aged 12 and 16 years there was no significant difference between MCT for translational and radial optic flow at either speed.

Various studies that have used RDKs have reported similar results to ours for translational, radial and rotational patterns, even using quite different stimulus parameters (Aaen-Stockdale, et al., 2007; Bertone & Faubert, 2003; Blake & Aiba, 1998; Ledgeway & Smith, 1994; Simmers, et al., 2006). MCT for translational, radial and rotational flow has been shown to be constant for stimulus exposure durations ranging from 240 to 750ms (Bertone & Faubert, 2003) and for different contrast levels (Aaen-Stockdale, et al., 2007; Simmers, et al., 2006). Similarly, different motion types have been shown to have no effect on MCT in young adults at a stimulus speed of 5.6°/s (Allen, et al., 2010).

Other studies have reported significant differences between the three different types of optic flow pattern, with better MCTs for both radial and rotational optic flow than translational using RDKs (Freeman & Harris, 1992) and gabor patterns with multiple apertures (Lee & Lu, 2010). However, these studies used relatively low speeds (2 sec of arc and 1.58°/s, respectively), which might account for the differences in MCT. We also found higher MCTs for translational flow at a stimulus speed of 1.56°/s. Lower MCTs for radial motion compared with circular motion have been reported at dot speeds of 8.4°/s and 30°/s (Beardsley & Vaina, 2005). This study however used a graded motion pattern with a high dot lifetime (11 frames) and the task was to detect small changes in the direction of optic flow. Since this study evaluated a different function at relatively high speeds, comparison with the present study might not be appropriate.

Translational optic flow is predominantly processed in area MT, while more complex optic flow patterns are processed in the higher cortical structure of MST. The translation information processed at MT is passed onto MST. Previous studies which found similar sensitivity has explained the finding as implying no loss of information during processing of translation between MT and MST (Aaen-Stockdale, et al., 2007). Greater sensitivity to complex motion, especially radial flow, has been reported in support of the high number of cortical areas involved in processing complex motion (Vaina & Rushton, 2004). Greater sensitivity to complex motion has been related to human need, as radial flow is the commonest form of optic flow experienced in real life. Our results suggest the presence of such an advantage for complex motion processing at lower speeds but not at higher speeds, indicating that at higher speeds all three optic flow patterns are processed with the same efficiency. The difference in sensitivity to translational flow and other optic flow patterns at lower speeds also suggests differences in the processing of faster and slower speeds, thereby supporting our suggestion of different motion channels, as discussed in the previous Chapter on the effect of stimulus speed.

4.4 The Effect of Contrast

The experiment on contrast was carried out in the pilot study to find the optimum contrast level for the main study. For all three optic flow patterns at both speeds, MCT was high for the lower level of contrast but fell as contrast increased levelling off at a contrast level of 5% to 8% . MCT has been reported to decrease with increasing contrast beyond a critical contrast level for translational, radial and rotational motion in normal adults (Aaen-Stockdale, et al., 2007;

Edwards, et al., 1996; Simmers, et al., 2006). The saturation of 15% (range 10% to 20%) contrast on the global motion threshold has been reported in a study that evaluated the effect of varying contrast from 3% to 80% for a translational pattern at a stimulus speed of 6°/s (Edwards, et al., 1996). In our study, MCT for the translational pattern at 5.6°/s appeared to saturate at 8%. Similar findings have been reported in young people, with saturation occurring at around 2%-4% contrast for translational, rotational and radial flow, after which MCT increased sharply (Allen, et al., 2010). Although Increases in MCT beyond a low level of contrast are consistent in various studies, the absolute level at which this occurs appears to vary. Both of the studies that reported 15% and around 2%-4% as critical contrast levels employed the same stimulus speed (5.6°/s) and stimulus size (12 degrees). However, both the number of dots and dot density differed. In our experiment, the saturation level occurred at around 5% to 8% contrast, after which decreasing contrast resulted in a significant increase in coherence threshold for all three motion types. Differences in saturation levels reported in other studies could be due to differences in stimulus parameters and procedures used for evaluation.

5.0 Concluding Remarks

This study clearly shows that sensitivity to complex global motion develops with age. Younger children are worse at detecting radial optic flow than older children and adults. The development of sensitivity to radial optic flow is dependent on speed, with sensitivity to higher speeds developing at a faster rate than to lower speeds. However, MCT in response to radial optic flow is not mature even at the age of 16 years, for either relatively high or relatively low speeds. In contrast, sensitivity to translational optic flow is mature at aged 8 years. The delayed maturation for radial optic flow perception reflects both the late development of visual functions that require higher level cortical processing, and the plasticity of the visual system.

Sensitivity to higher and lower speeds was different for all observers and all types of optic flow pattern. Sensitivity to the three optic flow patterns was similar at higher speeds but sensitivity to radial and rotational optic flow was enhanced at lower speeds in adults. The difference in sensitivity to optic flow patterns at slower and faster speeds in children and adults, together with varied development of radial optic flow perception at different speeds, suggests that different motion channels are involved in processing different motion speeds.

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7.0 Appendix

7.1 Protocol of Procedure

Subject will be comfortably seated at an appropriate distance from the computer screen displaying the experiment stimulus.

The illumination of room will be adjusted according to requirements.

Each subject will be given following information and instructions before the evaluation for motion perception will be initiated:

Stimulus

Test stimulus will be displayed in a circular aperture at the centre of the screen.

Stimulus will contain black and white dots moving at a certain speed in various directions.

Among the moving dots some will move in a defined direction while others will move randomly. Subject should fix at the centre of stimulus on the fixating dot.

Subject should respond in which direction majority of dots are moving. Response will be left and right for translation, expanding and contracting for radial and clockwise and anti clockwise for rotational movement.

Subject should not try to follow the single dot while determining the direction of the movement but look at the overall picture of the pattern of dots.

Response

Subject should respond by pressing either 1 or 3 key on the keyboard.

This is a forced choice test so even if one is uncertain about the direction of the dots, subject should press according to the most probable direction experienced.

The fixation dot will be green for the right response and red for the wrong response.

Subject is expected to make mistakes as the test becomes more difficult.

Demo

A demo version of stimulus will be first used for the experiment. The demo version will be kept at the threshold of 75%, with 15 reversals making it a shorter test and easier for the subject to appreciate the movement of the stimulus. If the subject responds with high percentage of correct response, examiner can be assured that the subject is confident with movement of stimulus and also the responding mechanism. After which, the final test will be instituted.

7.2 Information Sheet

BUSKERUD
University College

Information sheet on

"Motion Sensitivity in children and adult of Kathmandu Valley"

Background and purpose

This is to inform about a research study entitled "Motion Sensitivity in children and adult of Kathmandu Valley". This research intends to study the motion sensitivity development in children of various ages and compare it with the sensitivity in adults.

Motion detection is an integral part of our daily life as most of the object we perceive in environment is in motion. Motion perception develops throughout the childhood reaching an adult like level at a later stage than most other forms of visual perception. Defective motion perception is manifested in various ocular as well as systemic disorders such as Amblyopia, Learning disability (Dyslexia), Glaucoma and others. Knowledge regarding the development of motion perception can play a significant role in better understanding of many of these disorders. Information on motion perception from Nepali population can help in detection of these disorders and could provide useful information for developing any diagnostic test based on this strategy.

What does the study entail?

The study will be conducted in two phases, the screening and the examination phase. All the interested students of various age groups and adults will be screened for any ocular and visual abnormalities and detailed visual evaluation will be conducted. Those with normal visual acuity will be further involved in the study and those with no improvement with optical intervention will be referred to higher centre for further evaluation. The children and adult with normal visual acuity will be asked to sit through the stimulus experiment in which subject will have to response to visual stimulus through the computer system.

Potential advantages and disadvantages

All the participant will be screened prior to the further participation hence benefiting by having a regular eye check-up with full optical correction and referral to the higher ophthalmic centre if necessary. As there is evidence that motion perception is reduced in various disorders, the experiment tests might be helpful in detection of these disorders.

The entire evaluation will last for 30 to 45 minutes and does not enforce any involuntary and forceful response. As the study is a non interventional type, there are no potential adverse effects to the participants. There will be no discomforts to the participants as the study seeks to collect the data only through the voluntary response by the participants.

What will happen to the information gathered in study?

The data that are registered will only be used in accordance with the purpose of the study as described above. All the data will be processed without name, ID number or other directly recognisable type of information. A code number will link the data through a list of names.

Only authorised project personnel will have access to the list of names and be able to identify you. All the information regarding you and your participation will be deleted after the completion of the report of the study

Voluntary participation

Participation in the study is voluntary. Participant can withdraw the consent to participate in the study at any time and without stating any particular reason.

Further elaboration of what the study entails:

- Criteria for participation

  Any interested children from the age of 4 till the 14 years of age are welcome to participate in this study and also the adults of more than 18 years of age.

- The study participant's responsibility

  The participants will be responsible to response to the various visual stimuli that will be presented to them during the study experiment.

- All the procedure will be voluntary and does not require any intervention in the part of examiner. All the techniques applied have been in use in various similar research work and entails to danger or risk to the participants.

Privacy

Information that is registered about you will be used for the purpose of this research only and only the persons directly related to the study will have access to it. Anyone who has access to this data is bound to secrecy. The research team and the Høgskolen I Buskerud, is responsible for the data processing.

If have questions concerning the study, you may contact

Mahesh Raj Joshi, MPhil student
mahesh_raj@hotmail.com
+9779841355113, +4797101735

Supervisor:
Dr Helle K Falkenberg, PhD
helle.k.falkenberg@hibu.no

Information Sheet in Nepali Language

काठमाडौंका बच्चा तथा बयस्कहरुमा चाल सम्वेदनशिलताको अध्यन सम्बन्धि जानकारी

यो पत्र काठमाडौंका बच्चा तथा बयस्कहरुमा चाल सम्वेदनशिलता सम्वर्नधि जानकारीको लागि तयार गरिएको हो । यस अध्यनको उदेश्य बच्चाहरुमा चाल सम्वेदनसिलताको बिकाश कसरी हुन्छ र यो बयस्कहरुको सम्वेदनसिलताको स्तर कहिले पुरा हुन्छ भनि पत्ता लगाउनु हो ।

चाल सम्वेदनशिलता हाम्रो दैनिक कियाकलापको लागि अत्यावस्क छ । यो क्षमता वाल्यकाल देखि बिकास हुन्छ र बिस्तारै बयस्कको स्तरमा पुग्छ । आंखाका विभिन समस्याहरु जस्तै अल्छी आंखा, जलविन्दु, डिस्लेकसिया (पढनलाई सम्सया हुने) मा चाल सम्वेनशिलताको कमी हुने विभिन्न अध्यनले देखाएको छ। चाल सम्वेदनशिलताको बिकास सम्वर्नधि ज्ञानले यि विभिन रोगहरुको समयमा पहिचान र रोकथाममा महत्वपुर्ण भुमिका निर्वाह गर्छ। साथै यि रोगहरु पहिचान गर्ने उपकरण विकासमा पनि योगदन दिन्छ।

परिक्षण तथा अध्यन विधि

यस अध्यनमा समावेश हुने सम्पुण विधार्थीहरुको आंखा जांच गरिनेछ। उक्त जांचमा केहि खराबी देखिएमा त्यसको उपचारको यथोचित व्यवस्था गरिनेछ। जांच पछि सामान्य भेटिएका विधार्थिहरुको फेरि चाल सम्वेदनसिलता सम्वधि जांचहरु गरिनेछ।

सम्भावित फाईदा तथा बेफाइदाहरु

- सवै सहभागिहरुको आंखाको सम्पुर्ण जांचहररु गरिनेछ। जांचहरुमा केहि खराबी देखिएमा त्यसको उपचारको यथोचित व्यवस्था गरिनेछ। साथै सामान्य आंखा भएका बच्चाहरुमा पनि चाल सम्वेदनसिलता सम्वन्धी समस्या देखिनेंहुदा अरु विभिन्न रोगहरु पनि पत्ता लगाउन सकिनेछ।
- सम्पुण जांच प्रकिया ३० मिनेट भित्र सकिनेछ।
- यस अध्यनको तथ्याङ्कहरु गोप्य राखिनेछ र सम्बन्धित व्यक्तिहरुले मात्र यसको जानकारी राख्नेछन् ।

सहभागिता

- यस अध्यनमा सबै सहभगीहरु आफ्नो स्वेच्छाले भाग लिनेछन् र अध्यनको क्रममा कुनै कारण बिना कुनै पनि समय आफ्नो सहभागिता फ्रिर्ता लिन सक्नेछन।
- यस अध्यन सम्वन्धि अरु जानकारी चाहिएमा निम्न व्यक्तिसंग सर्म्पक गर्न सक्नुहुनेछ ।

महेश राज जोशी

९८४१३५५११३

7.3 Consent Form

BUSKERUD University College

Consent for participation in the study

"Motion Sensitivity in children and adult of Kathmandu Valley"

I have been informed and have understood the following:

The purpose, potential benefits and disadvantages of participating in the study ☐

That I can withdraw from the study at any time without giving any reasons and without fear ☐

That the data from my participation will be handled confidentially ☐

I am willing to participate in the study.

(Signed by the project participant, date)

I am willing for my child to participate in the study.

(Signed by the guardian, date)

Witness

(Signed by representative, date)

I confirm that I have given information about the study.

(Mahesh Raj Joshi)

Consent Form in Nepali Language

अध्ययनमा सहभागि हुन मन्जुरिनमा

“नेपालका बच्चा तथा प्रौढहरुमा चाल संबेदनशीलता”

मलाई यस अध्ययनका सम्भन्धमा निम्न लिखित जानकारी दिईएको छ र मैले यो सम्भन्धमा बुझेको छु।

यस अध्ययनका उद्यश्य, यस अध्ययनमा सहभागि हुँदा हुने सम्भाव्य फाइदा र बेफाईदाहरू | ☐

मैले कुनै कारणहरू बिना कुनै पनि समयमा अध्यनबाट फिर्ता हुन सक्ने स्वतन्त्रता। ☐

मेरो यस अध्ययनमा सहभागिताको आँकडा गोप्य रूप्मा समालिनेछन्। ☐

म यस अध्यनमा भाग लिन इच्छुक छु |

.....

(सहभागीको हस्ताक्षर,मिति)

म यस अध्ययनमा मेरो बच्चालाई भाग लिन लगाउन इच्छुक छु |

.....

(अभिभावको हस्ताक्षर,मिति)

साक्षी

.....

(हस्ताक्षर,मिति)

मैले यस अध्ययनको बारे जानकारी दिएको छु।

.....

(हस्ताक्षर,मिति), महेश राज जोशी

7.4 Nepal Health Research Council Approval

Nepal Health Research Council

Estd. 1991

NHRC

Ref. No. 84

Executive Committee

Executive Chairman
Dr. Chop Lal Bhusal

Vice - Chairman
Dr. Rishi Ram Koirala

Member-Secretary
Dr. Shanker Pratap Singh

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Dr. Narendra Kumar Singh
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Dr. Suman Rijal
Dr. Samjhana Dhakal
Dr. Devi Gurung

Representative
Ministry of Finance
National Planning Commission
Ministry of Health & Population
Chief, Research Committee, IOM
Chairman, Nepal Medical Council

August 1, 2010

Mr. Mahesh Raj Joshi
Principal Investigator
Department of Optometry and Visual Science
Buskerud University College, Norway

Ref: Approval of Research Proposal entitled **"Motion sensitivity in children and adult of Kathmandu Valley"**

Dear Mr. Joshi,

It is my pleasure to inform you that the above-mentioned proposal submitted on dated 14 June 2010 has been approved by NHRC Ethical Review Board on 29 July 2010 (2067-04-13).

As per NHRC rule and regulation, the investigator has to strictly follow the protocol stipulated in the proposal. Any change in objective(s), problem statement, research question or hypothesis, methodology, implementation procedure, data management and budget that may be necessary in course of the implementation of the research proposal can only be made so and implemented after prior approval from this council. Thus, it is compulsory to submit the detail of such changes intended or desired with justification prior to actual change in the protocol.

Further, the researchers are directed to strictly abide by the National Ethical Guidelines published by NHRC during the implementation of your research proposal.

As per your research proposal, total amount is US$ 850 and NHRC processing fee is US$ 100.

If you have any question, please contact our research section.

Thank you for your kind cooperation.

Sincerely Yours,

.....
Dr. Chop Lal Bhusal
Executive Chairman

7.5 Freiburg Visual Acuity Test

Freiburg Vision test was used to evaluate the visual acuity and contrast sensitivity. The "Freiburg Visual Acuity Test" is a computer generated automated procedure for visual acuity measurement. Visual stimuli in the form of landlord C were presented on a monitor and subject responded according to the stimulus. A psychometric function called Parameter Estimation by Sequential Testing (PEST) procedure was employed for the estimation of acuity threshold . Subjects were asked to response to varying level of visual acuity and contrast stimulus.

Procedure

Subjects were presented with varying level of visual acuity and contrast sensitivity stimulus in the form of landlord's C. Each eye was tested monocularly for both parameters. Subject had to respond by pressing one of the four choices of the direction of orientation of gap on the landlords C from the keyboard. For children of age group 10 and below, response was obtained verbally and the experimenter, blinded to the stimulus displayed on screen pressed the appropriate response button on the keyboard. After each test the result were stored on the Excel worksheet.

7.6 Sampling and Study Subjects

The target population of the study was school children between six and sixteen years from Kathmandu district, Nepal.

Sampling

There are 2213 primary to secondary level schools in Kathmandu district (G. o Nepal, Nov, 2009). Two schools were selected for the study. All students from age group between 6 (range 6.00 to 6.99) and 16 (range 16.00 to 16.99) years were included in the study.

Inclusion and Exclusion criteria

All students from two schools of Kathmandu district between the age 6 and 16 years were included in the study till required sample was obtained.

Exclusion criteria

Following children were excluded from the study

1. Children who had systemic and/or ocular disorders which might affect their performance in the experiment.
2. Children below 8 years who did not obtain best correction of log MAR 0.18 and Children above 8 years who did not obtain the best corrected vision of log MAR 0.00 after refraction.
3. Children who were uncooperative and could not complete the examination.

7.7 Examination Methods

Examination was carried out as following:

Vision Screening:

All the children and adults were screened by following procedure:

1. History regarding the ocular and systemic health
2. Visual acuity evaluation
3. Cover test to ascertain the binocular vision function
4. Anterior and posterior segment evaluation with ophthalmoscope

If the visual acuity was abnormal, children were subjected to the retinoscopy followed by subjective refraction for the best corrected visual acuity. Children whose visual acuity did not improve with the optical correction and/or has an abnormal ocular finding were referred to nearest ophthalmic centers.

Children with normal visual acuity or who improve with the best correction were evaluated by following methods.

1. Contrast sensitivity evaluation with Freiburg Vision test
2. Motion sensitivity with Random Dot Kinematogram

7.8 Screening Report

A total of 331 students from two schools were included. All students were evaluated with screening procedure.

Diagnosis of refractive error was made when the error was 0.50 dioptres or more spherical or cylindrical. Amblyopia was diagnosed when corrected visual acuity was worse than 6/9 in absence of any obvious ocular pathology.

Among the 331 students, 76 students has some ocular abnormality, 2 students had more than one disorder. One child had amblyopia with associated esotropia and another with myopia and exotropia. Among 76 children with ocular abnormality, refractive error was the major cause followed by squint. The distribution of ocular disorder is given in table below:

Diagnosis	Number
Amblyopia	2
Convergence Insufficiency	2
Refractive Error	
Myopia	38
Simple Myopic Astigmatism	12
Compound Myopic Astigmatism	8
Mixed Astigmatism	1
Simple Hyperopic Astigmatism	2
Hyperopia	1
Squint	
Alternate Divergent Squint	2
Intermittent Exotropia	3
Exotropia	1
Esotropia	1
Others	5
Total	78

First ten students from each age group of 6 to 16 years who satisfied the inclusion criteria for the experiments were further included in the study.

7.9 Research Protocol

Motion Sensitivity in children and adult of Kathmandu Valley

June 2010

Student: Joshi, Mahesh Raj

Supervisor: Falkenberg, Helle K

Introduction

Motion detection is an integral part of our daily life as most of the object we perceive in environment is in motion. Motion is perceived due to the changes in spatial distribution of light, over time which helps us to ascertain the speed and direction of objects. Motion perception is essential to our overall visual perception, our response to the changes in environment and even to our survival. While driving or crossing the street or to avoid colliding with other objects, motion perception is essential.

Motion perception is affected by various disorders of childhood including dyslexia. In Nepal there is little awareness about this disorder and failure to succeed academically is only taken as a lack of effort from the children. The mechanism for early detection and referral for treatment is essential to achieve the best possible outcome for children with learning disability as seen in dyslexia ("Joint statement--Learning disabilities, dyslexia, and vision," 2009).

Process of Motion perception

Visual information is processed from the retinal cells to the lateral geniculate nucleus along the magnocellular and parvocellular pathways to the primary visual cortex (Marcelja, 1979). Motion perception is a complex process involving various structures from retina to different parts of brain. Various parts of brain have been shown to be activated by motion. Single subject analysis on the functional magnetic resonance imaging has reported as many as 17 anatomically distinct areas being activated by motion (Sunaert, Van Hecke, Marchal, & Orban, 1999b).

Cells in the primary Visual cortex (V1) perform the first stage of motion processing which is activated by motion related stimuli. The superior Temporal area (Perrett et al., 1985) and dorsal extra straite area (V3A) has been shown to exhibit direction selectivity (Tootell et al., 1997) . The inputs from V1 cells are further processed in the Middle Temporal area (MT+ or V5 area). Most of the neurons in the V5 are direction selective and hence plays an important role in motion perception (Maunsell & Van Essen, 1983a). Different neural mechanism are involved in the processing of the motion, with cells in primary visual cortex signaling the direction of motion in local field and resulting in perception of global motion after integration of local motion signals across space (Smith, Snowden, & Milne, 1994).

Classification

The Visual system can perceive motion based on changes in luminance, contrast or texture over time. The perception based on luminance changes is called first order (Fourier) motion; perception based on other aspects (contrast/texture) is second order (non-Fourier) motion.

Processing of first order motion is believed to be a linear, arising within the primary visual cortex (V1) while the second order motion needs higher level of cortical processing in V3, VP area before its detection (Dumoulin, Baker, Hess, & Evans, 2003; Smith, Greenlee, Singh, Kraemer, & Hennig, 1998b).Studies have supported the notion that different neurological channels are involved in

processing of first and second order motion (Edwards & Badcock, 1995b; Ellemberg et al., 2005b; Ledgeway & Smith, 1994a; Rizzo, Nawrot, Sparks, & Dawson, 2008a).

Development of visual functions

It is well known that various visual functions develop and mature during the infancy and reach adult level at different ages (Ellemberg, Lewis, Liu, & Maurer, 1999b; Gordon & McCulloch, 1999b; Hong & Park, 2008b). It has been suggested that grating acuity, letter acuity, vernier acuity and distance stereo acuity are adult like by the age of 4 to 6 years (Ahmed, et al., 2005a; Zanker, Mohn, Weber, Zeitler-Driess, & Fahle, 1992a). Contrast sensitivity has also been reported to be mature by the age of 5 to 8 years, depending upon the stimulus used for the evaluation (Giaschi & Regan, 1997a; Hong & Park, 2008b; Scharre, Cotter, Block, & Kelly, 1990b).

Though there have been many studies detailing the development and maturation of various visual aspects they have mostly been the evaluation of the spatial vision and few works have detailed the development of motion sensitivity.

Like various visual perception, motion sensitivity also develops and matures through different age in children (Parrish, Giaschi, Boden, & Dougherty, 2005b). Infants are able to detect some limited visual motion and extract information leading to form perception (Kaufmann, 1995). Early visual deprivation as in congenital cataract has been reported to cause loses in motion sensitivity (Ellemberg, et al., 2005b).

It has been reported that first-order gratings thresholds are immature for infants (1.09 times worse than adults) and 5 year olds (1.03 times worse than adults) compared to adult levels (Lewis, Bhagirath, Ellemberg, & Maurer, 2003). The immaturity for five years old for both the first and second order motion is more pronounced for the slower speed stimuli (Ahmed, Lewis, Ellemberg, & Maurer, 2005b; Ellemberg et al., 2004a). The ability to identify motion defined letters develops by 7 to 8 years (Giaschi & Regan, 1997a). The immaturity for the first order motion persists even at the age of 10 (Armstrong, Maurer, & Lewis, 2009b).
With ageing there is decrease in sensitivity to motion (Bennett, Sekuler, & Sekuler, 2007), the decrease is more for the second order motion than for the first order when compared between the elderly and young adults (Billino, Bremmer, & Gegenfurtner, 2008a; Habak & Faubert, 2000).

Clinical use

Motion perception is altered or defective in various ocular anomalies affecting children such as dyslexia (Conlon, et al., 2009; Talcott, Hansen, Assoku, & Stein, 2000), autism (Bertone, Mottron, Jelenic, & Faubert, 2003), low birth children (MacKay, et al., 2005) and amblyopia (Simmers, Ledgeway, Hess, & McGraw, 2003a). Pattern deprivation amblyopia can result in severe residual global motion deficit even after the recovery of visual acuity in childhood (Constantinescu, Schmidt, Watson, & Hess, 2005).Motion perception is also affected in various disease of adults like Alzheimer's disease (G. C. Gilmore, Wenk, Naylor, & Koss, 1994b; Rizzo & Nawrot, 1998), lesions of brain (L. M. Vaina, Soloviev, Bienfang, & Cowey, 2000) and glaucoma (Falkenberg & Bex, 2007a; Silverman, Trick, & Hart, 1990).

Glaucoma is the second leading cause of blindness worldwide (Quigley & Broman, 2006). Motion impairment precedes visual field loss in primary open-angle glaucoma (Wu, Coffey, Reidy, & Wormald, 1998) and the loss is greater for first order than second-order motion (Karwatsky, Bertone, Overbury, & Faubert, 2006).Tests based on motion sensitivity is an accurate and economical alternative to the conventional visual perimeters (Babalola, 2005b). Similarly test based on motion sensitivity has been suggested as a useful neuropsychological tool for identification of Alzheimer's disease(G. C. Gilmore, et al., 1994b).

Motion perception is an integral part of visual mechanism which involves structures from retina to various parts of brain with complex processing mechanisms. Motion perception develops

throughout the childhood, reaching an adult like level at a later stage than most other forms of visual perception. Defective motion perception is manifested in various ocular as well as systemic disorders. Knowledge regarding the development of motion perception can play a significant role in better understanding of many of these disorders. Information on motion perception from Nepali population can help in detection of these disorders and could provide useful information for developing any diagnostic test based on this strategy.

Rational/ Purpose

In the context of Nepal, the visual function is measured only in terms of visual acuity and less importance is given to obtaining information regarding other visual perception. There is no information regarding the maturation of motion perception in the Nepali population.

Prevalence of ocular morbidity is as high as 11% to 34,2% in school going children of Kathmandu depending upon the population evaluated, type of school and examination method used (B. P. Nepal, Koirala, Adhikary, & Sharma, 2003; Shrestha et al., 2006). Amblyopia is recognized as a cause of visual impairment in children as well as in general population (Brilliant et al., 1985; Sapkota, Adhikari, Pokharel, Poudyal, & Ellwein, 2008; Shrestha, et al., 2006). A hospital based study has reported 5.97% of children and young adult to have amblyopia (Karki, 2006). Similarly Glaucoma has been reported as a major cause of visual impairment in Nepal (Brilliant, et al., 1985). As the diagnostic tool for glaucoma can be very expensive a simpler test based on motion sensitivity can be helpful for the screening purpose. Hence the baseline information regarding the motion sensitivity could be helpful in any future pursuit of such instrument.
The information of motion perception hence could provide an insight into detection of various disorders of children and adults. It also could be influential in developing strategies for various tests of ocular pathology diagnosis.

Objectives

General:
To evaluate the normal development and maturation of the motion perception in the children of Kathmandu, Nepal

Primary goals:

a. To evaluate how sensitivity to direction and speed develop and mature in children.
b. To develop a suitable computer based test set up that can be used to measure speed and direction sensitivity in school-aged children.

Secondary goals:

c. To evaluate the contrast sensitivity and visual acuity in the normal children of Kathmandu.
d. To evaluate whether motion sensitivity and contrast sensitivity /visual acuity is related

Method and Methodology

Study Design**:** This will be descriptive and quantitative study.

Sampling and study subjects

Target population: School going children of five to fourteen years (+/- 3 months) from Kathmandu district, Nepal

Sampling

There are in total 2213 schools in Kathmandu district for students from primary to secondary level of schooling; the prescribed age for these schools being 5-14 years. The schools in Kathmandu is categorized as, government and Institutional (Private) school (G. o. Nepal, Nov, 2009).

A random selection of school will be made from the various government and private schools of Kathmandu. One school each from the Government and Private school will be obtained. All the students from the age group of 5 to 14 years will be included in the study to acquire the required sample. The sample will be taken with equal number of male and female students, as far as possible. If there is inadequate sample from the two schools another school will be randomly selected to obtain the required number of samples.

The adult population will be obtained by recruiting student volunteers from the Institute of Medicine, Tribhuvan University.

Sample Size

Phase I (Pilot Study)

Initial pilot study will be conducted involving 20 children from any randomly chosen school and 10 adults.

Phase II

A sample of 15 children will be obtained in each age group from 5 till 14 with the class interval of one year thereby attaining the total sample size of 150 children. Similarly 25 adults with normal ocular and systemic health of more than 18 years of age will also be recruited for the study.

Informed consent will be obtained from the children and their guardians as well as the adult participants for the study. A detailed consent form describing the procedure of the study, its significance and effect on the participating children will be developed for this purpose.

Inclusion criteria: All school going children of Kathmandu district of Nepal willing to take part in the study from the age of 5 to 14 years and the adults more than 18 years.

Exclusion criteria

1. Children with systemic and ocular disorders which might affect their performance in the experiment.
2. Children who do not obtain the best corrected vision of log MAR 0.18 after refraction.
3. Children who are uncooperative and could not complete the experiment.

Examination method

Phase I

Examination will be carried after vision screening (Appendix A) followed by the experiment test.

Method:

Children with normal visual acuity or who improve with the best correction (Log MAR 0, 18) after screening will be further evaluated with following tests

1. Visual acuity and contrast sensitivity evaluation with Freiburg Vision (‘FrACT’) test

Visual acuity and contrast sensitivity will be evaluated with the help of Freiburg Vision test Subject will be asked to response to varying level of visual acuity and contrast stimulus.

The “Freiburg Visual Acuity Test” is a computer generated automated procedure for visual acuity measurement. Visual stimuli (like Landolt-Cs and alphabtes) are presented on a monitor and subject responds according to the stimulus (Bach, 1996b, 2007b). A psychometric function called Parameter Estimation by Sequential Testing (PEST) procedure is employed for the estimation of acuity threshold.

2. Motion sensitivity with Random Dot Kinematogram

An experiment stimulus to evaluate the motion perception will be developed. The psychophysical tasks for motion sensitivity will be programmed in Matlab computer software and run on a laptop computer. The stimulus based on the random dot kinematograms will be used for the purpose which is a standard psychophysical stimulus used to study the properties of low-level motion detectors. A dense pattern of random black-white dots is displaced coherently in one direction or the opposite, and the observer report perceived direction.
Stimuli for both the Freiburg Vision ('FrACT') test and motion perception will be displayed on 15.4" monitor with resolution of 32 bit and refresh rate of 75Hz. Acer Travel Mate 5730 laptop with Mobile Intel® GM45 Express Chipset display card will be used. Standard Computer keyboard will be used for the response from participants.
Results gathered from the pilot study will be analyzed and a review will be conducted.

Phase II

Data of Phase I will be analyzed and modifications will be done, if required. The modification will only be in the stimulus and instrumentation of the tests, the procedure will not change significantly. The methods used for the Phase I will be employed after necessary modifications.

Variables

1. Age, 2. Sex, 3. Visual Acuity, 4. Contrast Sensitivity, 5. Motion Sensitivity

Data Collection, tools and analysis

Data of the experiment will be collected and stored in the computer itself during the examination. Demographic data and results of the examination will be stored using Microsoft Excel program worksheet.

After data collection, all the personal information will be coded to anonymise the data to protect the privacy of the participants. Only the code will be used for further data analysis, and all personal information will be destroyed once the project is completed.

The extremes values will be evaluated during the experiment itself and the test repeated as required to substantiate the validity of the extreme values and included for evaluation.

Data analysis will be conducted with the help of Microsoft Excel and SPSS computer software. Various parametric and non parametric statistical analyses like T- test, Z test, ROC curve, ANOVA will be used as necessary.

Report dissemination and publishing

An initial report describing the basic outcome and performance of children will be provided to the schools, the school authority will in turn provide the report to interested parents.

Report of the data will be presented at national as well as international symposiums, meetings and conferences as appropriate. Final report will be submitted to the university as a part of Master thesis. The report will also be submitted to credible peer reviewed scientific journal for publication for which Joshi MR will be main author and Falkenberg HK will be co-author.

Ethical Consideration

The study will consider all the ethical aspects and will follow the Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects.

The study subject and their guardians will be informed in written in advance about

- Procedure of the examination and study

- Voluntary participation
- The right to withdraw from the study without stating reason at any time
- Description of confidentiality

Detailed information sheet and consent form (Appendix B) will be prepared and Informed consent will be sought from participants and guardians.
As the study subjects are children, utmost consideration will be given to ensure their comfort during the study period.
Ethical approval will be sought from the relevant authority for the study.

Organization

The principal investigator and co investigator will be responsible for carrying out various aspects of the study with help from the support staff as necessary. The personnel for primary involvement will be responsible for the defined tasks. The Secondary involvement will be to guide and help the principal investigator as necessary.

Tasks	Primary involvement	Secondary involvement
Protocol and stimulus finalization	Mahesh R Joshi	Helle K Falkenberg
Pilot study	Mahesh R Joshi	
Finalisation after pilot study	Mahesh R Joshi	Helle K Falkenberg
School Sampling & Interaction	Mahesh R Joshi	
Examination of children and adults	Mahesh R Joshi	
Data entry	Mahesh R Joshi	Helle K Falkenberg
Data Analysis	Mahesh R Joshi	Helle K Falkenberg
Report Writing	Mahesh R Joshi	Helle K Falkenberg
Final report	Mahesh R Joshi	Helle K Falkenberg

Plan of Work (Timeline)

Work Detail/ Time period	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2011	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Protocol and stimulus finalization																					
Study subject allocation (pilot study)																					
Pilot study																					
Finalisation after pilot study																					
School Sampling & Interaction																					
Examination of children and adults																					

Data entry																					
Data Analysis																					
Report Writing																					
Final report																					

Budget Detail:

Items available to the investigators and the university

1. Equipments
    a. Computer and display system
    b. Refraction set
    c. Ophthalmoscope
2. Data Analysis
3. Report writing

Items that need funding: (From the investigator)

SN	Items	Units/Cost	Total cost (USD)
1	Field Expenses		200
2	Transportation (Local)		120
3	Stationary		100
4	Printing		120
5	Display Unit		
6	Accessory Equipments (Bluetooth Keyboard, Mouse, Loan of hand held slit lamp)		150
7	Participants welfare (Free spectacles distribution for children)		Funding will be sought (If possible)
8	Others (emergency fund)		120
	Total (USD)		810

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