CHAPTER 1

INTRODUCTION AND PROBLEM IDENTIFICATION

1.1. Introduction

Stroke is the first cause of disability and second most frequent cause of mortality after ischemic heart disease in adults worldwide. An estimated 5.5 million subjects in the world die every year as a result of stroke, while two-thirds of patients who sustain a stroke in countries with developing market economies die as a result of the stroke (Salinas & Medina, 2007). Stroke causes a major public health challenge due to a high fatality rate and an increased number of stroke survivors dependent on the health care system, caregivers and their communities (Heller, Langhorne & James, 2000; Langhorne, Coupar & Pollock, 2009).

Long-term care, complete or partial working incapacity of patients post-stroke and the lack of community support contribute to enormous costs for patients, their families, caregivers, communities and the health care system. According to the United Nations, approximately 75% of the world's population lives in underdeveloped countries with 215 million people in Sub-Saharan African countries living below the threshold of the absolute poverty level (Salinas & Medina, 2007).

The life expectancy in countries with a developing market economy has increased from approximately 40 to 63 years over the last four decades. However, it is estimated that an inevitable increase in the incidence of chronic diseases such as stroke will continue to occur in these developing market economies. The prevalence of stroke in South Africa is estimated as 2.43 per 1000 population (WHO, 2004). The

available evidence strongly suggests that cerebrovascular disorders in Africa are rapidly becoming indistinguishable from those observed in developed countries (Salinas & Medina, 2007).

Moderate functional impairments are observed in 40% of people who have survived a stroke. Fifteen to thirty per cent of people who have survived a stroke present with severe disability following the stroke (Duncan et al, 2005). The increased prevalence of stroke in South Africa emphasises the importance of effective and evidence-based rehabilitation. The growing number of patients that survive a stroke, places an increased pressure on the limited number of rehabilitation therapists in both the public and the private sector in South Africa. It is therefore of utmost importance that the effectiveness and efficiency of rehabilitation of patients who sustain a stroke continuously be evaluated and, if necessary, be revised (Lannin & Herbert, 2003; Pollock, Baer, Pomeroy and Langhorne, 2007).

Functional disability can be minimised by the implementation of effective rehabilitation interventions early after stroke. Effective rehabilitation interventions initiated after the stroke can enhance the recovery process and result in improved functional outcomes in patients that suffer a stroke. Improved functional outcomes for patients who sustain a stroke also contribute to the patient's satisfaction, quality of life and community reintegration. Increased functional outcomes potentially reduce costly long-term expenditures (Duncan et al, 2005).

Since motor behaviour, perception and cognition are essential to basic activities of daily living (BADLs) such as transfers, toileting and dressing as well as instrumental

activities of daily living (IADLs) such as cooking, shopping and cleaning, the regaining of motor-, perceptual and cognitive function are essential for an individual's recovery of functional independence and return to daily living in the home and community environments post-stroke (Shumway-Cook & Woollacott, 2007). IADLs require higher-level neurophysiological organisation than is required for BADLs and are central to achieve independent living (Duncan et al, 2005).

Many stroke patients suffer from visual efficiency processing deficits; visual information processing system impairments and associated visual field defects (Jobke, Kasten, & Sabel, 2009). Some studies suggest that as many as 30% or more of all stroke survivors have some form of visual impairment (Das & Huxlin, 2010). Visual impairment in stroke patients may present with various ocular and visual impairments including gaze palsies, eye movement disorders and visual field defects as a result of damage to the primary visual cortex (V1) or its immediate afferents (Jones & Shinton, 2006; Das & Huxlin, 2010). Post-stroke patients with visual system impairment specifically impaired saccadic eye movements will experience decreased oculomotor visual performance resulting in slower saccadic eye movements, decreased control and coordination of eye movements resulting in the disruption of visual scanning and attention.

Visual and ocular impairments that result in reduced visual perception, cognition, executive function and motor behaviour caused by stroke lead to substantial functional disability during daily life activities and, thus, functional outcome. These patients may be impaired in many day-to-day activities such as safe mobilisation, navigating in complex environments, reading and driving (Schulmann, Godfrey &

Fisher, 1987; Pierce & Buxbaum, 2002; Leigh, & Kennard, 2004; Bowen & Lincoln, 2007; Chaiken, 2007; Shumway-Cook & Woollacot, 2007; Spering & Gegenfurtner, 2008; Nelles et al, 2009; Schuett et al, 2009; Das & Huxlin, 2010; Martin & Huxlin, 2010).

Impairments of oculomotor control, saccadic eye movements, smooth pursuit eye movements, convergent fusion, accommodation, unilateral homonymous hemianopia and homonymous visual field disorders are strikingly common in stroke patients but are rarely assessed and treated (Kerkhoff, 2000; Gilhotra et al, 2002; Linden et al, 2005; Jones & Shinton, 2006; Bouwmeester, Heutnik & Lucas, 2007; Nelles et al, 2009; Schuett et al, 2009; Das & Huxlin, 2010). Therapists are seldom concerned with participants' visual status and therefore rarely assess, monitor or direct patients' visual activity during therapy. In the absence of specific intervention, visual deficits stabilise and become permanent due to poor or almost absent spontaneous recovery of the visual system in stroke patients (Kerkhoff, 2000; Gilhotra et al, 2002; Linden et al, 2005; Jones & Shinton, 2006; Bouwmeester et al, 2007; Schuett et al, 2009; Das & Huxlin, 2010).

1.2. Limitations in the literature

A lack of evidence on the integration of visual scanning exercises through saccadic eye movement training as part of, and integrated with, physiotherapy has been identified in the literature regardless of the important role vision plays in movement and, ultimately, the functional ability of the patient.

From the literature reviewed that assessed the re-training of the visual system on patients' post-stroke's functional ability, perceptual processing and cognition post-stroke, it may be summarised that: (a) decreased visual efficiency processes, specifically impaired saccadic eye movements give rise to slower oculomotor speed, decreased control and coordination of eye movements resulting in disruption of visual scanning and attention; and (b) interventions that incorporate saccadic eye movement training with visual scanning techniques post-stroke improve the visual system with an associated improvement in perceptual processing, cognitive function and motor behaviour (Weinberg et al, 1977; Weinberg et al, 1979; Weinberg et al, 1982; Carter et al, 1983; Young et al, 1983; Webster et al, 1984; Gordon et al, 1985; Ball et al, 1988; Gur et al, 1992; Kerkhoff et al, 1992; Pizzamiglio et al, 1992; Wagenaar et al, 1992; Kerkhoff et al, 1994; Ladavas et al, 1994; Antonucci et al, 1995; Fanthome et al, 1995; Zihl et al, 1995; Paolucci et al, 1996; Kalra et al, 1997; Wiart et al, 1997; Niemeier et al, 1998; De Sèze et al, 2001; Nelles et al, 2001; Bailey et al, 2002; Brunila et al, 2002; Ciuffreda, 2002; Pierce & Buxbaum, 2002; Cappa et al, 2003; Pambakian et al, 2004; Pizzamiglio et al, 2004; Sabel et al, 2004; Bolognini et al, 2005; Cicerone et al, 2005; Rawstron et al, 2005; Bouwmeester et al, 2007; Mueller et al, 2007; Nelles et al, 2009; Roth et al, 2009).

Limitations highlighted in the review of studies that assessed the effects of visual therapy in patients who suffered a stroke were, first, the effect of intervention that addressed ocular and visual impairments were mainly assessed using paper-and-pencil tasks during visual-perceptual assessment. However, the reviewed studies did not provide an indication of change in an individual's ability to function in the complex everyday activities that are relevant to their life (Weinberg et al, 1977;

Weinberg et al, 1979; Weinberg et al, 1982; Carter et al, 1983; Young et al ,1983; Webster et al, 1984; Gordon et al, 1985; Ball et al, 1988; Gur et al, 1992; Kerkhoff et al, 1992; Pizzamiglio et al, 1992; Wagenaar et al, 1992; Ladavas et al, 1994; Fanthome et al, 1995; Zihl et al, 1995; Bailey et al, 2002; Brunila et al, 2002; Ciuffreda, 2002; Pierce & Buxbaum, 2002; Cappa et al, 2003; Cicerone, 2005; Rawstron et al, 2005; Reinhard, 2005; Goh, 2007; Jobke et al, 2009; Nelles et al, 2009).

Second, few researchers have evaluated the long-term effects of interventions that addressed ocular and visual impairments in patients post-stroke (Webster et al, 1984; Gordon et al, 1985; Ball et al, 1988; Kerkhoff et al, 1994; Niemeier, 1998; Bolognini et al, 2005).

Third, only a few studies have assessed the effects of re-training of the visual system on the individual's subjective well-being and quality of life (Kerkhoff et al, 1994; Nelles et al, 2001; Pambakian et al, 2004; Sabel et al, 2004; Bolognini et al, 2005; Reinhard et al, 2005; Goh, 2007; Mueller et al, 2007; Jobke et al, 2009).

From the limitations identified in the review of literature, it is concluded that outcome measures used in the research setting to evaluate the outcome of an intervention that incorporates saccadic eye movement training with visual scanning exercises should include assessment of the patient on body impairment level, functional activity- and participation levels. Also, assessment of the outcome of the intervention which aims to improve ocular and visual impairments post-stroke with associated improvements in cognitive function, perceptual processing, motor function and perceived quality of life should include assessment of body impairment level, functional activity- and participation levels. Visual scanning training through saccadic

eye movement exercises integrated into increasingly complex visual-perceptual and visual-motor tasks needs be assessed with a matched-pair randomised controlled trial (Chan, Chan & Au). Through a matched-pair randomised controlled trial the extent to which visual scanning training transfers to functional ability and quality of life in patients with visual impairments following stroke can be assessed.

1.3. Practical experience of the researcher

In practice the researcher has discovered that the integration of visual scanning exercises through saccadic eye movement training during task-specific activities as part of the treatment of unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke results in an improvement in functional ability, earlier discharge from the rehabilitation setting and good functional carry-over of acquired skills to "real life situations". This observation and the lack of the integration of saccadic eye movement training with visual scanning exercises during task-specific activities urged the researcher to investigate the effect of visual scanning exercises integrated with task-specific activities as part of physical rehabilitation in patients who have sustained a stroke and who suffer from unilateral spatial inattention, visual-spatial disorders or visual-constructive disorders.

Limitations experienced in both literature and clinical practice are that rehabilitation approaches used in the treatment of the motor system, perception and cognition focus only on the facilitation of recovery of the different subsystems as a single entity and not as an integrated holistic approach where the visual, perceptual, cognitive and gross motor activities are integrated in normal movement and functional activities.

Rehabilitation interventions aiming to optimise functional recovery in stroke patients therefore need to incorporate the restoration of sensory / perceptual, motor and cognitive impairments, in order to increase functioning on both activity and participation levels. There is a need for evidence that saccadic eye movement training during task-specific activities results in better outcome on body impairment level, functional activity and participation level in the treatment of patients who experience unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke.

1.4. Problem statement

A lack of evidence on the integration of visual scanning exercises as part of, and integrated with, physiotherapy has been identified in the literature regardless of the important role vision plays in movement and ultimately the functional ability of the patient. Schulmann et al (1987) recommend that visuomotor training should be encouraged amongst the post-stroke population to enhance postural strategies in patients with postural control impairment secondary to stroke. Patients with decreased postural control may be trained to use re-fixation saccadic eye movements to enable them to obtain a stable visual field for peripheral vision. Peripheral vision is utilised to provide the spatial orientation for postural control.

The aim of visuomotor therapy is to address the oculomotor system – specifically the oculomotor control impairments, which entail saccadic eye movements, smooth pursuit eye movements, accommodation and convergence disorders and their mutual interactions. The goal of treatment is not to address these impairments in isolation, but to integrate oculomotor control with the sensomotor system to facilitate efficient

and coordinated behaviour within a context of appropriate spatial sense under a variety of external and internal conditions and environments (Ciuffreda, 2002).

There is a need for evidence that saccadic eye movement training during task-specific activities results in improved outcome on body impairment level, functional activity and participation level in the treatment of patients with visual-perceptual disorders following a stroke. In order to determine whether the integration of visual scanning through saccadic eye movement training has a more permanent or long-term effect on patients' postural control, functional ability and quality of life, it would be important to perform assessment of the effect thereof on a longitudinal basis.

1.5. Significance of the research

If the evidence from the study shows that saccadic eye movement training with visual scanning exercises integrated with task specific activities as an intervention has a significant effect on cognitive functioning, oculomotor visual performance, functional ability and quality of life in participants that present with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke, the evidence will contribute to an evidence-based holistic understanding of treatment strategies in the field of stroke rehabilitation. The evidence will further contribute to an understanding of the role of vision in postural control and rehabilitation of patients who have sustained a stroke (Teasell et al, 2011).

1.6. Research questions

(1) What is the effect of saccadic eye movement training with visual scanning exercises integrated with task-specific activities versus patients who have only received the task-specific treatment approach on:

- **Oculomotor visual performance;**
- **Functional ability;**
- **Perceptual processing and cognitive functioning; and**

in patients who have sustained a stroke and present with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders, after four (4) weeks of rehabilitation, as well as eight (8), twelve (12), sixteen (16) and twenty (20) weeks after rehabilitation has been terminated?

(2)   What is the effect of saccadic eye movement training with visual scanning exercises integrated with task-specific activities versus patients who have only received the task-specific treatment approach on **quality of life** in patients who have sustained a stroke and present with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders eight (8), twelve (12), sixteen (16) and twenty (20) weeks after rehabilitation has been terminated?

1.7. Aims of the study

The aims of this study were to determine:

(1)   The effect of task-specific activities as an intervention approach versus the effect of visual scanning exercises integrated with task-specific activities as an intervention approach on participants that presented with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke's:

- Oculomotor visual performance;

- Functional ability; and

- Perceptual processing and cognitive functioning;

on a weekly basis during the intervention period of four (4) weeks as well as eight (8), twelve (12), sixteen (16) and twenty (20) weeks after rehabilitation has been terminated.

(2)   The effect of task-specific activities as an intervention approach versus the effect of visual scanning exercises integrated with task-specific activities as an intervention approach on participants that presented with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke' quality of life eight (8), twelve (12), sixteen (16) and twenty (20) weeks after rehabilitation has been terminated.

1.8. Objectives of the study

The objectives of this study were to determine:

(1) The effect of visual scanning exercises integrated with task-specific activities received by participants in Group 1 versus participants in Group 2 that received task-specific activities alone on participants' that presented with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke's **oculomotor function** measured with the **King-Devick Test ©** on a weekly basis during the intervention period of four (4) weeks as well as eight (8), twelve (12), sixteen (16) and twenty (20) weeks after rehabilitation has been terminated.

(2) The effect of visual scanning exercises integrated with task-specific activities received by participants in Group 1 versus participants in Group 2 that received task-specific activities alone on participants that presented with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke's **functional ability** measured with the **Stroke Activity Scale, Barthel Index** and **Timed Up and Go Test** on a weekly basis during the intervention period of four (4) weeks as well as eight (8), twelve (12), sixteen (16) and twenty (20) weeks after rehabilitation has been terminated.

(3) The effect of visual scanning exercises integrated with task-specific activities received by participants in Group 1 versus participants in Group 2 that received task-specific activities alone on participants that presented with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke's **perceptual processing** and **cognitive functioning** measured with the **Star Cancellation Test** and **Mini-Mental State Examination** on a weekly basis during

the intervention period of four (4) weeks as well as eight (8), twelve (12), sixteen (16) and twenty (20) weeks after rehabilitation has been terminated.

(4) The effect of visual scanning exercises integrated with task-specific activities received by participants in Group 1 versus participants in Group 2 that received task-specific activities alone on participants that presented with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke's **quality of life** measured with the **Stroke Impact Scale Version 3.0** and the **Walking ability questionnaire** eight (8), twelve (12), sixteen (16) and twenty (20) weeks after rehabilitation has been terminated.

1.9. Ethical approval

Ethical approval to conduct this study was granted by the Ethics Committee of the Faculty of Health Sciences at UP (S33/2009) (Addendum 1). Permission to conduct this study in the Physiotherapy Department at the TRC in Pretoria, Gauteng, South Africa was granted by the Acting Chief Executive Officer of TRC (Addendum 2).

1.10. Course of the study

In Chapter 1 the need for this study, aims and objectives of the study are discussed.

In Chapter 2 the role of the visual system in optimising postural control in participants who have suffered a stroke is identified and explained. The chapter also reviews the visual therapy interventions used to address disorders of the visual system and recovery in the post-stroke population.

In Chapter 3 a detailed account is given on how the research was performed. This account includes the research setting, the recruitment of patients, the matching and allocation of participants, the research process and the assessment procedure of participants from Group 1 that received visual scanning exercises integrated with task-specific activities received by participants versus participants from Group 2 that received task-specific activities alone.

In Chapter 4 the results of the research methodology are presented in tables and graphs. A detailed account of the analysis of the data and a discussion of the results gathered during the matched-pair randomised controlled trial are presented in Chapter 4. The demographical data of all the participants who participated in this clinical trial as well as the results of the outcome measures obtained at the pre-determined times are identified and described in Chapter 4.

In Chapter 5 the results of the trial are discussed in the context of the relevant literature. The conclusion of the effect of saccadic eye movement training with visual scanning exercises integrated with task-specific activities on participants that presented with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke's functional outcome after four (4) weeks of rehabilitation are discussed. The limitations of the study and suggestions for further studies are also discussed in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

In Chapter 2 the existing research evidence and limitations in the evidence on the influence of impairment of the visual system has on the patient's functional ability are discussed. The published interventions used to address disorders of the visual system in the stroke population to improve impairments of oculomotor control, saccadic eye movements, smooth pursuit eye movements, convergent fusion, accommodation, unilateral homonymous hemianopia and homonymous visual field disorders are reviewed.

Patients with visuomotor deficits, visual-perceptual and cognitive impairments following a stroke may present with the following impairments during functional activities (Chaikin, 2007):

1) Avoidance of near (close-up) tasks;
2) Neglecting one side of the body or space during the performance of an activity;
3) Losing the place when reading;
4) Bumping into walls or objects during walking or when maneuvering in a wheelchair;
5) Difficulty with activities of daily living due to poor eye-hand coordination – knocking objects over or missing objects during reaching;
6) Appearing to misjudge distance;

7) "Under reaching" or over reaching for objects;

8) Closing or covering one eye during conversations and/or activities due to blurred vision or double-vision;

9) Squinting;

10) Seeming to look past the observer and having difficulty maintaining eye contact; and

11) Decreased attention during conversations and/or activities (patient day dreams)

Patients with visuomotor deficits, visual-perceptual and cognitive impairments following a stroke may suffer from the following ocular and visual impairments (Chaikin, 2007):

1) Blurred vision;

2) Having difficulty "seeing" with or without glasses;

3) Double-vision;

4) Letters jumping around on the page during reading;

5) Experiencing eye strain or headaches;

6) Portions of the page being missing when reading;

7) Portions of objects not being observed;

8) Not seeing people or objects approaching suddenly from one side; and

9) Having difficulty concentrating on tasks

Visual and ocular impairments that result in reduced visuomotor deficits, visual-perceptual and cognitive impairments caused by stroke lead to substantial impaired

functional ability during activities of daily living in and around the house, in the work environment, community and recreational environment. The therapy interventions used to address disorders of the visual system that includes impairments of oculomotor control, saccadic eye movements, smooth pursuit eye movements, convergent fusion, accommodation, unilateral homonymous hemianopia and homonymous visual field disorders should be evaluated. The result of training of the visual system on patients' functional ability, perceptual processing and cognition following a stroke should also be reviewed.

2.2. Literature search strategy

A search for relevant literature using multiple databases was used to identify all potential literature on therapy interventions used to address disorders of the visual-perceptual system, cognitive processing and the possible influence of impairment of the visual system on the patient's functional ability.

The literature search excluded animal trials and was restricted to articles in the English language only. The search strategy included articles published from 1970 – 2011 and included (1) randomised controlled trials (RCTs); (2) case studies; (3) Cochrane reviews prepared and maintained by The Cochrane Collaboration and published in *The Cochrane Library*; (4) clinical observational studies; (5) quasi-experimental studies; (6) systematic literature reviews; and (7) retrospective case reviews.

Various Internet search engines were also used to obtain relevant literature for this clinical trial. These included:

- Google Scholar

- Electronic library of University of Pretoria:

  - Science Direct

  - Pubmed

  - PEDro

  - Cochrane

  - Cinhal

- Websites: http://www.ebrsr.com/ = Evidence-based of Stroke Rehabilitation

  http://who.com/ = World Health Organization

  http://wcpt.com/ = World Confederation for Physical Therapy

- Keywords that were used are:

  - Stroke

  - Postural control

  - Physical therapy

  - Rehabilitation approaches for stroke patients

  - Motor control

  - Physiotherapy

  - Motor learning

  - Cognition

  - Perception

  - Sensorimotor integration

  - Visual scanning

  - Eye movements

  - Saccades / Saccadic eye movements

  - Activities of daily living

  - Neurovisual rehabilitation

  - Task-orientated activities

  - Visual learning

  - Executive function

- Bibliographies of articles selected were also reviewed for relevant additional literature.

2.2.1. Assessment of the quality of selected literature

In the case of RCTs the quality of the research was evaluated according to the PEDro scale for RCTs: http://www.pedro.fhs.usyd.edu.au/scale. Formulation of conclusions according to the levels of evidence was based on the Eastern Ontario / Queen's Evidence Based Report. The report is based on the levels of evidence used by the United States Agency for Health Care Policy and Research (AHCPR) Guidelines for Stroke Rehabilitation (Teasell, 2011).

2.3. Functional activity and the visual system post-stroke

Visual efficiency processes that mainly consist of saccadic eye movements, visual fixation and smooth pursuit eye movements are controlled by a complex neural system. Smooth pursuit eye movements are used to maintain the eyes on a target, where saccadic eye movements are necessary to visually scan the surrounding environment to provide an individual with information on spatial relation and temporal-spatial relationships that includes: (a) the identification of objects' position in space; (b) the determination of the objects' movement; (c) the position of one's body in space; (d) the relation of one body part to another and (e) the motion of one's own body (Gorman, 2007; Shumway-Cook & Woollacot, 2007). Impairment to control gaze or to shift gaze appropriately to scan the environment will limit the visual system's input into postural-orientation processing and as a result affect postural

stability and ultimately result in the inability to execute goal-directed activities (Das & Huxlin, 2010).

Many patients suffer from ocular and visual impairments following either a haemorrhagic or ischaemic stroke (Jobke, Kasten & Bernhard, 2009; Roth et al, 2009). Visual system impairments observed in patients who have suffered is summarised in Table.2.1.

Table 2.1. Visual system impairments post-stroke (Maddock et al, 1981; Schulmann et al, 1987; Zoltan, 1996; Kerkhoff, 2000; Leigh & Kennard, 2004; Chaikin, 2007; Shumway-Cook & Woollacott, 2007; Spering & Gegenfurtner, 2008; Schuett et al, 2009)

Visual impairment	Definition and Explanation
Accommodation	The ability of the eye to vary its refractive power to produce a focused image on the retina for different object distances (Maddock et al, 1981).
Unilateral homonymous hemianopia/Homonymous visual field defects (HVFDs)	Loss of vision in both monocular hemifields contralateral to the side of the stroke (Schuett et al, 2009). Unilateral homonymous hemianopia is the most frequent visual disorder following damage to the V1 or its postchiasmal afferents. Damage to the V1 occurs in patients as result of a stroke in the territory of the posterior cerebral artery infarction affecting the postchiasmatic visual pathway (Leigh & Kennard, 2004; Pambakian et al, 2004; Bolognini et al, 2005; Bouwmeester, Heutink & Lucas 2007; Schuett, Kentridge, Zihl & Heywood, 2009; Das & Huxlin, 2010).

Visual impairment	Definition and Explanation
	Twenty to thirty per cent (20 – 30%) of patients with stroke presents with homonymous visual field disorders, resulting in poor rehabilitation progress and therefore decreased functional ability (Das & Huxlin, 2010).
Unilateral spatial inattention and hemianopia	The inability to perceive stimuli on one side of the body resulting in neglect of one side of the body and extrapersonal space on that side (Shumway-Cook & Woollacot, 2007).
Binocular vision/convergent fusion disorder	To direct the eyes to a target nearer than the present fixation point (Kerkhoff, 2000). Thirty per cent (30%) of patients with stroke show reduced convergent fusion resulting in poor rehabilitation progress and therefore decreased functional ability (Das & Huxlin, 2010).
Eye movement disorder: Conjugate eye deviation/Saccadic eye movement impairment	The inability to shift eyes rapidly from object to object, therefore not allowing quick localisation of movements observed in the periphery (Chaikin, 2007).
Eye movement disorder: Smooth pursuit disorder	Impairment in the tracking (following) of a moving visual object of interest when the head is stationary (Schulmann et al, 1987; Zoltan, 1996; Spering & Gegenfurtner, 2008).
Visual spatial perception disorder	Impairment in the perception of vertical and horizontal orientation. Impairment in the perception of the length, size and position discrimination of objects (Kerkhoff, 2000).

Visual and ocular impairments displayed in Table 2.1 may result in (1) small saccadic eye movements; (2) decreased speed of saccadic eye movements towards the impaired visual field; (3) a narrow scope of saccadic eye movements with visual

scanning in the visual field; and (4) slower speed, poor control and decreased coordination of saccadic eye movements, visual fixation and smooth pursuit eye movements. Dysfunction of saccadic eye movements, visual fixation and smooth pursuit eye movements result in the following impairments on body impairment level:

- o Difficulty in localisation of other objects in relation to the individual itself (extrapersonal perception);
- o Difficulty in localisation of the individual in relation to other objects (intrapersonal perception);
- o Inability to maximise peripheral vision by not being able to provide a stable visual field;
- o Inability to bring near objects into clear focus automatically and without strain;
- o Difficulty to keep an image of a moving object stationary on the fovea while the static background (the peripheral visual field) appears to move;
- o Increased visual exploration time, target omissions and unsystematic oculomotor scanning patterns;
- o Inability to examine the details of the extrapersonal visual environment of an individual, resulting in a visual-spatial dysfunction;
- o Impaired visual orientation and visual search in two-dimensional (2D) and three-dimensional (3D) spaces;
- o Impaired orientation during self-motion of a person; and
- o The inability to track and maintain the image of a moving object on the fovea of the eye.

The inability to perform smooth pursuit movements and visual fixation to track and maintain the image of a moving object on the fovea of the eye results in an impairment of central vision. Central vision dysfunction gives rise to impairment in the analysis of objects and result in functional deficits that include impairment of eye-hand coordination and difficulty with visually directed movement for fine motor tasks and gross movement.

Dysfunction of saccadic eye movements, visual fixation and smooth pursuit eye movements on body impairment level result in impairment of spatial orientation as result of an unstable visual field resulting in an impairment of depth perception and subsequent inaccuracy in judgement of distances. These visual and ocular impairments increase difficulty with peripersonal and intrapersonal ADL which includes (1) self-care and hygiene activities; (2) dressing, specifically closing fasteners and doing buttons; and (3) difficulty finding objects.

Impairment of saccadic eye movements results in body image impairment due to a lack of spatial orientation and attention to one half of the individual's intrapersonal space which may limit the performance of ADLs to one half of the body for example (1) eating food on one side of the plate; (2) dressing only one side of the body; (3) shaving one side of the face; (4) applying make-up to only half the face; (5) brushing teeth in only half the mouth; (6) missing kitchen utensils if they are located on the affected side; and (7) failure to recognise their affected extremities as their own and function as though they are absent.

Difficult and unsafe mobilisation due to the patient failing to see obstacles in their hemianopic field result in (1) increased risk of falls; (2) attempting to navigate through

a door oblivious to the fact that the affected arm may be caught on the doorknob or doorframe; (3) walking into objects present in the neglected side; (4) unsafe mobilisation over uneven surfaces and stairs; (5) unsafe mobilisation in the community; (6) when walking or driving a wheelchair veering towards the unaffected extrapersonal space rather than navigating in a straight line; and (7) unawareness of doorways and hallways in the affected extrapersonal space as well as turning in only one direction may result in these individuals losing their way and getting lost.

Absent visual scanning using saccadic eye movements on the affected side of the midline of the body defects give rise to (1) impaired reading due to impaired viewing of words toward the end of the lines, skipping individual words within a line and repetition of lines; (2) inability to change direction of fixation particularly at the end of a line; (3) losing the place on the total page; (4) slow reading speed, guessing errors and severely altered reading eye-movement pattern; (5) filling out only one half of a form; (6) reading only half the page; and (7) difficulty with letter identification resulting in deficits in reading. Difficulty with reading, writing and typing as result of impaired saccadic eye movements and visual fixation leads to difficulty in the workplace with relation to accuracy of work, management of workload and working speed. Patients may also have difficulty with computer-based tasks due to (1) poor concentration; (2) reduced sustained visual attention in near-work conditions; and (3) blurred vision as result of the dysfunction of saccadic eye movements, visual fixation and smooth pursuit eye movements on body impairment level.

Impairment of saccadic eye movements, visual fixation and smooth pursuit eye movements result in extensive functional impairments in the community and

recreational environment. Patients may have difficulty in recreational activities and hobbies such as (1) assembling a puzzle; (2) playing board games; and (3) using tools in building of models and woodwork.

Visual and ocular impairments on body impairment level influence functional activities on participation level in the sense that patients may experience difficulty in the identification and following of moving objects in the visual field periphery. The inability to perform saccadic eye movements, smooth pursuit movements and visual fixation may result in difficulty to (1) identify and follow moving vehicles, persons and moving objects in the extrapersonal visual surroundings; (2) difficulty with driving; and (3) difficulty in detecting vehicles or persons to avoid collisions.

For an extended period of time it was believed that visual impairments including visual efficiency processes and visual information-processing skills – such as visual field defects, oculomotor control, accommodation and convergence dysfunctions following stroke – were untreatable. The concept of plasticity of the brain and visual system has emerged in the neurosciences over the last two decades. It is now well recognised that the visual system shows modifiability and potential to recover from lesion-induced changes (Sabel & Kasten, 2000; Sabel et al, 2004; Mueller, Mast & Sabel, 2007).

A literature review on the effect of the re-training of the visual system post-stroke highlights recent developments in the re-training of the visual system and the resulting functional recovery in patients following a stroke (Das & Huxlin, 2010). A

summary of the results of previous studies that assessed the effect of re-training of the visual system on patients' functional ability post-stroke is displayed in Table 2.2.

Table 2.2. Results of previous studies that assessed the effect of re-training of the visual system on patients' functional ability post-stroke (Das & Huxlin, 2010; Teasell et al, 2011)

Articles published from 1970 – 2011	Levels of evidence
Ten (10) studies presented evidence for the effect of re-training of the visual system on patients' functional ability post-stroke. These studies included: Seven (7) randomised controlled trials One (1) case study One (1) open non-randomised clinical trial One (1) clinical observational study	Strong evidence (Level 1a) consisting of seven randomised clinical trials of fair quality (3 studies), good quality (1 study) and of excellent quality (3 studies) concludes that treatment incorporating visual scanning techniques through saccadic eye movement training improves the visual system post-stroke with associated improvements in function.
Forty (40) studies presented evidence for both short-term and long-term effect of treatment incorporating saccadic eye movement training with visual scanning exercises with associated improvements in oculomotor strategies and visual efficiency processes, cognitive function, visual-perceptual processes, independence in ADL, mobility and ambulation. These studies included: Eighteen (18) randomised controlled trials Two (2) quasi experimental studies Eleven (11) case studies Six (6) literature reviews One (1) open randomised clinical trial One (1) retrospective case review One (1) clinical observational study	Strong evidence (Level 1a) consisting of sixteen (16) randomised clinical trials of fair quality (5 studies), good quality (9 studies) and of excellent quality (2 studies) concluded that treatment incorporating visual scanning techniques through saccadic eye movement training improves the visual function post-stroke and is associated with improvements in oculomotor strategies, visual efficiency processes and function.

Articles published from 1970 – 2011	Levels of evidence
The improvement of motor impairment and restoration of motor function should focus on high-intensity, repetitive task-specific practice with feedback on performance (Pollock et al., 2007 & Langhorne et al., 2009).	The systematic review, however, did not include any studies that utilised and incorporated saccadic eye movement training with visual scanning exercises integrated into physiotherapy.

In RCTs performed between 1970 and 2011 (Table 2.2.) the conclusion can be made that: (1) No studies used or incorporated saccadic eye movement training with visual scanning exercises integrated into physiotherapy.

(2) **Visuomotor training** should be encouraged to enhance postural strategies of patients with postural control impairment secondary to stroke. Patients with decreased postural control may be trained to scan their peripheral visual field using re-fixation **saccadic eye movements** which aim to provide a stable visual field for peripheral vision. Peripheral vision is used to provide spatial orientation for postural control during the performance of functional tasks in everyday life (Schulmann et al, 1987).

(3) Treatment utilising and incorporating saccadic eye movement training with visual scanning exercises improves **oculomotor strategies and visual efficiency processes** in patients post-stroke.

(4) Visual scanning exercises that incorporate saccadic eye movement training improves ocular and visual impairments resulting in **associated improvements in functional ability**.

(5) Saccadic eye movement training with visual scanning exercises integrated with task-specific activities does not improve ocular and visual impairments in isolation, but integrate oculomotor control with the:

- Motor system to facilitate eye-hand coordination;

- Extremities to improve eye-hand and eye-foot coordination; and

- Overall body and other sensory modalities to produce efficient and coordinated behaviour within a context of appropriate spatial sense under a variety of external and internal conditions and environments (Ciuffreda, 2002).

Based on literature reviewed in Table 2.2. it can be concluded that intensive saccadic eye movement training can re-train and strengthen a patient's oculomotor strategies and visual efficiency processes. Improved oculomotor strategies optimise the visual system of patients post-stroke and further improve their ability to use vision in everyday life which results in improved functional ability in terms of independence during activities of daily living in and around the house, in the work environment, community and recreational environment.

2.4. Visual system, visual perception and cognition

Decreased oculomotor function, visual efficiency processes and saccadic eye movements result in reduced visual perception and cognition, which results in substantial functional disability during daily life activities (Kerkhoff, 2000; Nelles et al, 2009). The presence of decreased oculomotor function, visual efficiency processes and saccadic eye movements are, therefore, associated with visual perceptual dysfunction and decreased cognitive functioning.

Perceptual dysfunction is an important cause of long-term disability in patients who have suffered a stroke. Impairments of the perceptual system can adversely affect a patient's ability to safely and efficiently mobilise in and around the house as well as at

work and in the community. Perceptual impairments also affect the patient's ability to perform most tasks in the work environment, reading and enjoyment of many recreational activities. Perceptual impairments therefore severely affect a stroke survivor's overall quality of life (Martin & Huxlin, 2010).

2.4.1. Perceptual processing

Perception is the integration of multiple sensory input through the individual sensory systems and sensory strategies into meaningful information that is fundamental to the successful performance of functional tasks in a particular environment (Shumway-Cook & Woollacott, 2007). Unilateral spatial neglect (inattention) is a visual-perceptual disorder that entails the inability to perceive and integrate stimuli on one side of the body, resulting in the neglect of the intrapersonal or extrapersonal space of one side of the body. USN or hemi-inattention is characterised by a disturbance in spatial perception affecting the contralateral side of the body. This visual-perceptual deficit may occur in up to 50% of patients with stroke affecting the right cerebral hemispheres and up to 25% of left hemispheric stroke (Diserens et al, 2007).

Visual-perceptual dysfunction is caused by the impairment of central associative processing of primary visual input obtained through visual efficiency processes that mainly consist of saccadic eye movements, visual fixation and smooth pursuit eye movements. USN is the most disruptive impairment of visual scanning, with fewer eye movements observed to one side of body or extrapersonal space during the performance of an activity. With careful observation of a patient's activity the fovea of the eye does not appear to be directed to gather information from one side of the body or extrapersonal space. Visual scanning using saccadic eye movements occurs

on only one side of the midline within the unaffected side of the body. Spontaneous eye movements or head movement past the midline into the affected space is absent (Zoltan, 1996; Chaikin, 2007).

Visual-perceptual dysfunction, specifically unilateral spatial neglect (USN), is a major cause of disability and impairment in stroke patients that negatively influences functional recovery and is, therefore, associated with poor functional outcome (Fanthome et al, 1995; Kalra, 1997; Cassidy et al, 1998; Kerkhoff, 2000; Cherney, 2001; Bailey et al 2002; Cappa et al, 2003; Jones & Shinton, 2006; Luauté et al, 2006; Chaikin, 2007). Regardless of the side of the stroke (Kalra, 1997), visual-perceptual deficits are rarely observed in isolation. They **present in combination** with motor, language and **cognitive dysfunctions**. The presence of these impairments delays the progress of rehabilitation, as visual-perceptual disorders are highly associated with deficits in functional activities in the home-, work-, community- and recreational environment (Kerkhoff, 2000; Linden et al, 2005; Luauté et al, 2006).

2.4.2. Cognitive functioning

Impairment of cognitive function is a significant cause of disability following a stroke. Cognitive dysfunction may result in reduced efficiency, speed and persistence of functioning and decreased effectiveness in the performance of routine ADL. Individuals with cognitive impairment also fail to adapt to novel or problematic situations. Stroke patients with cognitive impairments present with extensive functional disability at discharge from acute hospital settings, increased length of stay in rehabilitation facilities, increased hospital resource use, and increased duration of therapy input (Kalra, 1997; Carter, 1983; Chaikin, 2007; Martin & Huxlin, 2010).

Visual scanning with saccadic eye movements allows individuals to examine the details of our extrapersonal visual environment to provide the visual sensory information that precedes motor actions (Land, 2009). During visual scanning the saccadic eye movements and visual fixation **are preceded by a shift of attention** to the goal of the next saccade (Leigh & Kennard, 2004). Efficient and effective visual scanning is therefore **dependent on cognitive factors**, which include planning, sequencing, visual-spatial attention, and spatial working memory to optimise saccadic eye movements and visual fixation (Leigh & Kennard, 2004).

Active visual scanning is **dependent upon the integration of visual attention and oculomotor control**. Therefore, an attentional deficit may impair a patient's ability to search and scan the extrapersonal visual space surrounding him. Impairment of visual scanning ability may contribute to cognitive dysfunction that negatively influences postural control and, as such, the level of functional independence post-stroke (Leigh & Kennard, 2004). Attention to a specific part of the visual field also benefits visual processing in that area of the visual field. Attention is distributed across the visual field to improve visual-information processing by means of improving the efficiency with which stimuli are detected and discriminated between (Poggel et al, 2004).

Patients who suffered a stroke are likely to exhibit multiple forms of cognitive impairment. It is therefore essential to continually evaluate the effectiveness of integrated therapy that addresses the complex interaction between cognitive impairments, functional disability, perceptual dysfunction and participatory impairments with the goal of reducing disability and improve functional ability in and around the house, in the work environment, community and recreational environment

(Cicerone et al 2000). Results of studies reviewed in the literature that assessed the effect of re-training of the visual system on patients' perceptual processing and cognitive function post-stroke are summarised in Table 2.3.

Table 2.3. Results of studies that assessed the effect of re-training of the visual system on patients' perceptual processing and cognitive function post-stroke (Das & Huxlin, 2010; Teasell et al, 2011)

Articles published from 1970 – 2011	Levels of evidence
Forty (40) studies presented evidence for both short-term and long-term effect of treatment incorporating saccadic eye movement training with visual scanning exercises with associated improvements in oculomotor strategies and visual efficiency processes, **cognitive function**, **visual-perceptual processes**, independence in ADL, mobility and ambulation. These studies included: Eighteen (18) randomised controlled trials Two (2) quasi experimental studies Eleven (11) case studies Six (6) literature reviews One (1) open randomised clinical trial One (1) retrospective case review One (1) clinical observational study	Strong evidence (Level 1a) consisting of sixteen (16) RCTs of fair quality (5 studies), good quality (9 studies) and of excellent quality (2 studies) concluded that treatment incorporating visual scanning techniques through saccadic eye movement training improves the visual function post-stroke and is associated with improvements in oculomotor strategies, visual efficiency processes and function.
Sixteen (16) studies presented evidence for both short-term and long-term (sustained) effect of treatment incorporating saccadic eye movement training with visual scanning exercises assessed by standardised cognitive outcome measures. The paper-and-pencil cognitive outcome measures	Strong evidence (Level 1a) consisting of ten (10) RCTs of fair quality (2 studies), good quality (7 studies) and of excellent quality (1 study) concludes that treatment incorporating visual scanning techniques through saccadic eye movement training improves the visual system post-stroke with associated

Articles published from 1970 – 2011	Levels of evidence
used in the studies provide an indication of changes in the underlying cognitive impairment (Bowen & Lincoln, 2007). These studies included: Ten (10) randomised controlled trials Two (2) quasi experimental studies (n = 77) and (n = 12) Two (2) case studies (n = 5) and (n = 13) Two (2) literature reviews	improvement in cognition.
In the InChanti study (2005) (n = 926) the association between performance on tests of cognitive processes (executive function) and performance on lower extremity tasks were researched. This cross-sectional study concluded that cognitive and executive function is **independently associated** with tasks of lower extremity function that require high attentional demand (Ble et al, 2005; Yogev et al, 2008).	
Similar findings were reported by Holtzer et al. (2006) (n = 186) where the researchers demonstrated associations between speed of cognitive processing, attention, memory, language, executive function, and gait speed.	
Associations between cognitive function, executive function and performance of balance and mobility were observed in stroke patients (n = 63) even after adjustment for age, quadriceps strength of the paretic side, and current physical activity level (Liu-Ambrose et al, 2007).	

The presence of visual and ocular impairments that includes decreased oculomotor function specifically decreased saccadic eye movements and visual fixation is associated with visual perceptual dysfunction and decreased cognitive functioning. In the literature summarised in Table 2.3. it is clear that impairment of visual-perceptual

processing and cognitive functioning result in impairments on body impairment level such as (1) decreased ability to learn; (2) inattention; (3) decreased arousal (decreased level of consciousness) and orientation (disorientation); (4) impaired memory; (5) impairment of problem-solving ability; (6) decreased self-awareness; (7) decreased planning; (8) decreased response inhibition and monitoring; (9) loss of mobility due to reduced motivation; and (10) decreased inner drive to move.

The effect of the decreased visual-perceptual processing and cognitive functioning on body impairment level as result of dysfunction of saccadic eye movements, visual fixation and smooth pursuit eye movements result in difficulty during performance of functional tasks in and around the house, workplace and recreational environment as described in paragraph 2.3.

Based on the results of RCTs performed between 1970 and 2011 (Table 2.3.) certain conclusions can be made. These are numbered 1 to 8 below.

(1) No studies used or incorporated saccadic eye movement training with visual scanning exercises integrated into physiotherapy in the treatment of perceptual processing and cognitive functioning in patients post-stroke.

(2) Treatment incorporating saccadic eye movement training with visual scanning exercises improves the visual system post-stroke **with associated improvements in perceptual processing and cognitive functioning**.

(3) The re-training of visual scanning, specifically saccadic eye movements, should be emphasised as part of the rehabilitation of patients post-stroke. Increased ability to perform visual scanning, specifically saccadic eye movements, should be incorporated in systematically increasingly complex visual-perceptual and visual-

motor tasks. Visual scanning, specifically saccadic eye movements, should be further emphasised and integrated during functional tasks such as gait and dressing. The influence of perceptual processing specifically USN and cognitive functioning on functional performance should be continuously monitored by objective and subjective testing.

(4) Clinicians need to evaluate cognitive function when assessing and treating impaired balance and mobility in community-dwelling adults after stroke. Cognitive impairment is a significant cause of disability following a stroke and result in reduced efficiency, speed and persistence of functioning in the performance of functional activities in and around the household, workplace and community.

(5) The association between cognition, balance and mobility in fall-prevention need to addressed in the rehabilitation of patients following a stroke.

(6) The consequences of spontaneous plasticity for perception appear to be relatively limited. Persistent loss of visual perceptual abilities, the impact on visual functions in everyday life and impaired quality of life **persist** in the long term in the majority of patients with visual system dysfunction following a stroke and where no intervention were provided.

(7) Many studies which attempted to retrain perceptual dysfunction by using visual scanning exercises with saccadic eye movements, observed a major unresolved issue – the functional significance of improvements in vision during the performance of activities of daily living.

(8) The effects of the research intervention were only assessed with paper-and-pencil tests and tasks. No assessment of the effects of the research intervention on functional ability was performed. Therefore, the functional effects of that particular intervention remain unknown and gives rise to the question; "How does the improved

performance on objective and subjective measures assessing visual function post-stroke translate to the ability to perform visually guided activities of daily living?

2.5. Anxiety and depression

In the literature published between 1970 and 2011 it is clear that the cognitive and physical consequences of stroke are influenced by the presence of depressive disorders in patients who suffered a stroke. Major depressive disorder is associated with a significantly greater degree of cognitive impairment following a stroke, although cognitive impairment does not result in post-stroke depression (Dam et al, 1989; Egelko et al, 1989; Burvill et al, 1995; Shimoda & Robinson, 1998; Talelli et al, 2004; Kalaria & Ballard, 2001; Jaillard et al, 2010).

An anxiety disorder following a stroke influences and slows down the course of recovery from the stroke by influencing the severity and course of depression; independence during the performance of activities of daily living and course of recovery in terms of social functioning at long-term follow-up (Astrom, 1996; Shimoda & Robinson, 1998). The presence of an anxiety disorder however does not affect cognitive impairment, which is influenced only by major depression. Cognitive impairment associated with depression is therefore not altered by a comorbid anxiety disorder. This suggests that depression and anxiety disorders are caused by different mechanisms of origin (Shimoda & Robinson, 1998).

The incidence of post-stroke depression (PSD) has been reported to be as large as 68%, with major depression reported in as many as 27% of stroke survivors

(Diserens et al, 2007). The presence of depression is significantly associated with the presence of cognitive impairment following stroke (Dam et al, 1989, Egelko et al, 1989; Burvill et al, 1995; Shimoda & Robinson, 1998; Talelli et al, 2004; Kalaria & Ballard, 2001; Jaillard et al, 2010). Murata et al (2000) concluded that major post-stroke depression leads to cognitive impairment, although cognitive impairment does not result in post-stroke depression.

2.6. Assessment of the effects of treatment on impairment, activity, and participation levels

The assessment of functional outcome is done using assessment tools that focus on the measurement of the functional outcome of the patient and quantifying the underlying impairments that constrain functional performance (Horak et al, 1997).

Assessment on functional activity level and treatment of motor disorders, language and speech are traditionally viewed as critically essential in the rehabilitation of patients who have sustained a stroke. However, the influence of visual-sensory and oculomotor disorders on the patient's functional outcome is still neglected in the rehabilitation of patients with neurological impairments (Kerkhoff, 2000; Ciuffreda et al, 2007). The neuroplasticity of the visual system provides the neurobiological substrate for a rationale and scientifically based visual rehabilitation strategy (Sabel & Kasten, 2000). The extent to which the positive effect of saccadic eye movement training with visual scanning exercises can transfer to other visually guided functional tasks and quality of life of patients with visual impairments following stroke should be assessed with a matched-pair randomised controlled trial (Sabel & Kasten, 2000; Chan, Chan & Au, 2006; Das & Huxlin, 2010; Martin & Huxlin, 2010).

2.7. Model of disablement used in this study

In this study the International Classification of Functioning, Disability and Health (ICF) (Ustun et al, 2003) was used as the model of disablement within which patients were assessed and treated. The ICF provides a conceptual distinction between the effects a stroke may have at different levels of body impairment, functional activity and participation levels (West, Bowen, Hesketh & Vail, 2009). The use of outcome measures assessing the effects of treatment on impairment, activity, and participation level is needed to determine the efficacy and also the direct relationship between saccadic eye movement training with visual scanning exercises on underlying impairments and the patient's functional ability on activity and participation levels.

2.7.1. Assessment of the effects of treatment on oculomotor function

An outcome measure were selected to assess the effect of visual scanning exercises integrated with task-specific activities received by participants from Group 1 versus participants from Group 2 that received task-specific activities alone on participants that presented with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke's **oculomotor function** measured with the **King-Devick Test ©**. The use of the **King-Devick Test ©** to assess the effects and the direct relationship between saccadic eye movement training with visual scanning exercises on patients' **oculomotor function** (underlying impairment), functional activity and participation levels are summarised in Table 2.4.

Table 2.4. The use of the **King-Devick Test ©** to assess the effects and the direct relationship between saccadic eye movement training with visual scanning exercises on patients' **oculomotor function** (underlying impairment), functional activity and participation levels

OCULOMOTOR FUNCTION		
THE KING-DEVICK TEST © (Zoltan, 1996)	**Body impairment level**	**Functional activity level and participation level**
The assessment of: (1) Residual oculomotor functions in the clinical setting (Markowitz, 2006; Chaikin, 2007). (2) Eye movements during reading (Markowitz, 2006; Chaikin, 2007; Galetta et al, 2011). (3) Attention (Galetta et al, 2011). (4) Language (Galetta et al, 2011). (5) Other correlates of suboptimal brain function (Galetta et al, 2011).	Oculomotor function is crucial to the efficient processing of visual information (Zoltan, 1996). Impaired oculomotor function results in: (1) Slower speed of saccadic eye movements, visual fixation and smooth pursuit eye movements. (2) Decreased control of saccadic eye movements, visual fixation and smooth pursuit eye movements. (3) Decreased coordination of saccadic eye movements, visual fixation and smooth pursuit eye movements.	Impaired oculomotor function severely impairs a patient's ability to effectively scan his/her environment and in turn result in functional impairment (Zoltan, 1996). Impaired oculomotor function results in difficulty with: (1) Localisation of other objects in relation to the (2) individual itself (extrapersonal perception) (3) The localisation of the individual in relation to other objects (intrapersonal perception) (4) Fine motor tasks (5) Activities that require eye-hand coordination (6) Gross movement and ambulation tasks - Walking through an aisle (7) Hygiene and self-care activities (8) Dressing

OCULOMOTOR FUNCTION		
THE KING-DEVICK TEST © (Zoltan, 1996)	**Body impairment level**	**Functional activity level and participation level**
		(9) Reading (10) Typing (11) Driving (12) Sporting activities

The identification of limitations in functional performance such as inability to walk independently outside the house and climbing stairs does not provide information on the underlying impairments such as impaired oculormotor control and impaired eye movements that may be constraining functional performance (Martin & Huxlin, 2010). The King-Devick Test © is a useful tool for the assessment of residual oculomotor functions in participants post-stroke (Markowitz, 2006; Chaikin, 2007). The test is an indicator of oculomotor visual performance for eye movements during reading and assesses residual oculomotor functions in the clinical setting (Markowitz, 2006; Chaikin, 2007).

The King-Devick Test © is based on the measurement of the speed with which the numbers was read aloud of three (3) subtests (reading aloud single digit numbers from three test cards – (Subtest 1, Subtest 2 and Subtest 3) and assesses impairment of eye movements, attention, language and other correlates of suboptimal brain function (Galetta et al, 2011). The level of difficulty increases as the participant progresses through the three (3) subtests in the sense that the King-Devick Subtest 2 requires larger saccadic eye movements and visual search strategies compared to King-Devick Subtest 1. The King-Devick Subtest 3 requires

larger saccadic eye movements and visual search strategies compared to King-Devick Subtest 2.

a. The King-Devick Subtest 1

The King-Devick Subtest 1 consists of randomly spaced numbers connected by horizontal lines. The patient is asked to call out numbers in the sequence that they are connected with the horizontal lines as fast as possible (Addendum 5). With the King-Devick Subtest 1 scores taken included (i) the time taken to complete the test (the time indicated the speed with which the test was completed); and (ii) the average errors made during the completion of the subtest.

b. The King-Devick Subtest 2

The King-Devick Subtest 2 consists of randomly spaced numbers without horizontal lines. The patient is asked to call out numbers in sequence (without connecting lines) from left to right as fast as possible. The King-Devick Subtest 2 increases with difficulty compared to King-Devick Subtest 1 in the sense that the King-Devick Subtest 2 requires larger saccadic eye movements and visual search strategies compared to King-Devick Subtest 1. The oculomotor strategies and visual efficiency processes, specifically the saccadic eye movements, required to complete the King-Devick Subtest 2 increased from King-Devick Subtest 1 to King-Devick Subtest 2 (Addendum 5). With the King-Devick Subtest 2 scores taken included (i) the time taken to complete the test (the time indicated the speed with which the test was completed); and (ii) the average errors made during the completion of the subtest.

c. The King-Devick Subtest 3

The King-Devick Subtest 3 consists of randomly spaced numbers, also without horizontal lines. The patient is asked to call out numbers in sequence from left to right as fast as possible. The King-Devick Subtest 3 is the most difficult subtest of the King-Devick Test © in the sense that the King-Devick Subtest 3 requires even larger saccadic eye movements and visual search strategies than to King-Devick Subtest 1 and King-Devick Subtest 2. With the King-Devick Subtest 3 scores taken included (i) the time taken to complete the test (the time indicated the speed with which the test was completed); and (ii) the average errors made during the completion of the subtest.

In each subtest scores taken included (i) the time taken to complete the test (the time indicated the speed with which the test was completed); and (ii) the average errors made during the completion of the subtests. Interpretation of the King-Devick Test © is displayed in Table 2.5.

Table 2.5. Interpretation of the King-Devick Test © – the King-Devick Subtest 1, Subtest 2 and Subtest 3

	Subtest 1	Subtest 2	Subtest 3
Time (seconds) taken to complete the subtest	14.86	16.87	18.73
Average Errors made in completion of the subtest	0.07	0.07	0.33

a. Validity and reliability of the King-Devick Test ©

The King-Devick Test © is used for the assessment of residual oculomotor function, impairment of eye movements, attention, language and is therefore an indicator of oculomotor visual performance for eye movements during reading in participants post-stroke (Markowitz, 2006; Chaikin, 2007). Although the test is quick, easy to score and can be administered by all members of the rehabilitation team, the researcher did not find any publication with regards to the test's reliability in the stroke population (Lieberman et al, 1983; Oride et al, 1986). The King-Devick Test © is used for children and adults (Zoltan, 1996; Galetta et al, 2011).

2.7.2. Assessment of the effects of treatment on functional ability

Outcome measure were selected to assess the effect of visual scanning exercises integrated with task-specific activities received by participants from Group 1 versus participants from Group 2 that received task-specific activities alone on participants that presented with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke's **functional ability** measured with the **Barthel Index** and **Timed Up and Go Test** on a weekly basis during the intervention period of four (4) weeks as well as eight (8), twelve (12), sixteen (16) and twenty (20) weeks after rehabilitation has been terminated. The use of the **Barthel Index** and **Timed Up and Go Test** to assess the effects and the direct relationship between saccadic eye movement training with visual scanning exercises on patients' f**unctional ability** are summarised in Table 2.6.

Table 2.6. The use of the **Barthel Index** and **Timed Up and Go Test** to assess the effects and the direct relationship between saccadic eye movement training with visual scanning exercises on patients' **functional ability** functional activity- and participation levels.

FUNCTIONAL ABILITY		
OUTCOME MEASURES	**Functional activity level**	**Participation level**
Barthel Index	The assessment of: Feeding Bathing Grooming Dressing Bowel control Bladder control Toileting Chair transfer Ambulation Stair climbing	Difficulty to effectively and efficiently perform activities outside the house. Unsafe mobilisation over uneven surfaces and stairs. Unsafe mobilisation in the community. Poor or inaccurate estimation of physical limitations that may result in inappropriate evaluation of environmental hazards and may increase the risk of falling.
Timed Up and Go Test	The ability to perform sequential motor tasks relative to walking and turning.	Walking into objects. Difficulty in the workplace with relation to typing, reading and writing. Difficulty in recreational activities and hobbies. Difficulty in social interaction in the household, workplace and community.

(1)   Barthel Index - Addendum 6

The Barthel Index assesses the performance of ten (10) common ADL regarding feeding, bathing, grooming, dressing, bowel control, bladder control, toileting, chair transfer, ambulation and stair climbing, as well as the patient's dependence (on assistance) to perform these activities (Mahoney & Barthel, 1965). The interpretation of the Barthel Index is displayed in Table 2.7.

Table 2.7. Interpretation of the Barthel Index (Shah et al, 1989)

Score	The Barthel Index
0 - 20	Total dependence
21 – 60	Severe dependence
61 – 90	Moderate dependence
91 – 99	Slight (minimal) dependence
100	Independent

a.   Validity and reliability of the Barthel Index

The stroke-specific outcomes measure present with excellent validity, reliability and adequate responsiveness (Salter et al, 2006). The calculated inter-rater reliability using the intraclass correlation (ICC) = 0.94 and the internal consistency using Cronbach's alpha rangres between 0.89 – 0.92. The BI also closely correlated with the Berg Balance Scale and the Fugl-Meyer motor assessment in patients with stroke (Pearson's correlation coefficient r ≥ 0.78 (Hsueh et al, 2001).

(3) The Timed Up and Go Test – Addendum 7

The Timed Up and Go Test (TUG) assesses mobility, balance and locomotor performance. It also assesses the ability to perform sequential motor tasks relative to walking and turning (Salter et al, 2006). The TUG assesses mobility, balance and locomotor performance. It also assesses the ability to perform sequential motor tasks relative to walking and turning (Salter et al, 2006). The interpretation of the TUG is displayed in Table 2.8 to Table 2.10.

Table 2.8. Interpretation of the Timed Up and Go Test (Podsiadlo & Richardson, 1991; Shumway Cook et al, 2000)

Time	The Timed Up and Go Test (TUG)	
< 10 seconds	Completely independent	With or without walking aid for ambulation and transfers
< 20 seconds	Independent for main transfers	• With or without walking aid. • Independent for basic tub or shower transfers. • Able to climb most stairs and go outside the house alone
20 - 30 seconds	Dependent	Impaired functional mobility
> 30 seconds	Requires assistance	Dependent in most activities – ADL & mobility skills
Unable to complete the test	Requires maximal assistance	Dependent in all ADL and mobility

Table 2.9. Interpretation of TUG and risk of falls (Podsiadlo & Richardson, 1991; Shumway Cook et al, 2000)

Time	The Timed Up and Go Test (TUG)
≥ 14 seconds	High risk of falls
≤ 13 seconds	Low risk of falls

Table 2.10. Interpretation of walking speed and community ambulation (Ada et al, 2009)

Walking speed	Community ambulation
0.3 m/s - 0.8 m/s	Able to mobilise in the community

a.   Validity and reliability of the Timed Up and Go Test

Results of two studies conducted by Flansbjer et al (2005) and Ng & Hui-Chan (2005) suggest that the TUG is a reliable and valid measure in patients with stroke. The test-retest reliability of the TUG was found to be excellent (ICC = 0.96) (Flansbjer et al, 2005) and ICC = 0.95 (Ng & Hui-Chan, 2005). An excellent correlation was found between the TUG and various gait performance measures that included comfortable gait speed, fast gait speed, stair climbing ascend, stair climbing descend and the Six-Minute Walk Test (ranging from r = - 0.84 to r = - 0.92) (Flansbjer et al, 2005). The correlation between the various gait performance measures and the TUG is a negative figure because a high score on the TUG indicates abnormal functioning whereas a high score on the gait measures indicate a high level of performance.

2.7.3. Assessment of the effects of treatment on perceptual processing and cognitive function

Outcome measure were selected to assess the effect of visual scanning exercises integrated with task-specific activities received by participants from Group 1 versus participants from Group 2 that received task-specific activities alone on participants that presented with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke's **perceptual processing** and **cognitive functioning** measured with the **Star Cancellation Test** and **Mini-Mental State Examination** on a weekly basis during the intervention period of four (4) weeks as well as eight (8), twelve (12), sixteen (16) and twenty (20) weeks after rehabilitation has been terminated. The use of the **Star Cancellation Test** and **Mini-Mental State Examination** to assess the effects and the direct relationship between saccadic eye movement training with visual scanning exercises on patients' **perceptual processing** and **cognitive functioning** are summarised in Table 2.11.

Table 2.11. The use of the **Star Cancellation Test** and **Mini-Mental State Examination** to assess the effects and the direct relationship between saccadic eye movement training with visual scanning exercises on patients' **perceptual processing** and **cognitive functioning** (underlying impairment), functional activity and participation levels.

PERCEPTUAL PROCESSING AND COGNITIVE FUNCTIONING		
OUTCOME MEASURES	**Body impairment level**	**Functional activity level and participation level**
Star Cancellation Test The assessment of: Unilateral Spatial Neglect	The inability to perceive and integrate stimuli on one side of the body resulting in neglect of one side of body (intrapersonal) or extrapersonal space.	ADLs are limited to one half of the body. Body image impairment due to a lack of spatial orientation and attention to one half of the individual's intrapersonal space. Unsafe mobilisation and impairment of depth perception that results in the subsequent inaccuracy in judgement of distances. Reading and writing difficulty due to absent visual scanning using saccadic eye movements on the affected side of the midline of the body.
Mini-Mental State Examination The assessment of: Attention Orientation Memory Problem solving Arousal (Level of consciousness)	Inability to focus on a specific stimulus without being distracted (Shumway-Cook & Woollacott, 2007). Inability to retrieve knowledge related to a specific person, place and time (Shumway-Cook & Woollacott, 2007). Inability to register, process, store and retrieve previously stored information (Shumway-Cook & Woollacott, 2007).	Difficulty with ADL and mobility. Difficulty in the workplace with relation to accuracy of work, management of workload and working speed. Difficulty in social interaction in the household, workplace and community. Disorientated in terms of person, place and time. Forget names and schedules.

PERCEPTUAL PROCESSING AND COGNITIVE FUNCTIONING		
OUTCOME MEASURES	**Body impairment level**	**Functional activity level and participation level**
	Inability to apply knowledge and information to new or unfamiliar situations (Shumway-Cook & Woollacott, 2007). Decreased basic arousal process allowing the patient to respond to stimuli in the environment (Shumway-Cook & Woollacott, 2007).	Inability to recognise threats to safety.

(1)   Star Cancellation Test – Addendum 8

The Star Cancellation Test was developed by Wilson, Cockburn & Halligan (1987) to identify the presence of unilateral spatial neglect (USN) and visual-spatial disorders in participants who have suffered a stroke. Scores of the Star Cancellation Test included (i) the average number of errors made during the completion of the test and (ii) the time taken to complete the test (speed).

Visual-perceptual dysfunction after a stroke may include a disorder of spatial awareness known as unilateral spatial neglect (USN). Unilateral spatial neglect (USN) is the inability to perceive and integrate stimuli on one side of the body, resulting in the neglect of one side of the body in the intrapersonal or extrapersonal space. USN is the most disruptive impairment of visual efficiency processes, which results in fewer eye movements observed on one side of the body or extrapersonal space during the performance of an activity. USN can selectively affect different sensory modalities, cognitive processes, spatial orientation and spatial awareness

(Halligan, Fink, Marshall & Vallar, 2003). The impairment may also affect an individual's ability to perform many everyday tasks such as eating, dressing and reading (Bowen & Lincoln, 2007).

Interpretation of the Star Cancellation Test is displayed in Table 2.12.

Table 2.12. Interpretation of the presence of unilateral spatial neglect

Score of Star Cancellation Test	Level of impairment
< 44 stars	Indicates the presence of unilateral spatial neglect (USN) in the near extrapersonal space.

a.   Validity and reliability of the Star Cancellation Test

The Star Cancellation Test presents with excellent validity, sensitivity and test-retest reliability (Intraclass correlation Coefficient = 0.89) (Menon & Korner – Bitensky, 2004; Bailey, Riddoch & Crome, 2004; Bailey, Riddoch & Crome, 2002, Chaikin, 2007).

(2) Mini-Mental State Examination (Folstein, Folstein & McHugh, 1975) – Addendum 3

Impairment of cognitive function is a significant cause of disability following a stroke. Cognitive dysfunction may result in reduced efficiency, pace and persistence of functioning and decreased effectiveness in the performance of routine ADL (Cicerone et al, 2000). The Mini-Mental State Examination (MMSE) was developed to provide a quantitative assessment of cognitive impairment and to record cognitive changes

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over time (Folstein, Folstein, & McHugh, 1975). Interpretation of the level of cognitive impairment (Folstein et al, 2001) is displayed in Table 2.13.

Table 2.13. Interpretation of the level of cognitive impairment (Folstein et al, 2001)

Score of MMSE	Level of impairment
≥ 27	No cognitive impairment
21 – 26	Mild cognitive impairment
11 – 20	Moderate cognitive impairment
≤ 10	Severe cognitive impairment

a. Validity of the Mini-Mental State Examination

Concentration, language and praxis, orientation, memory and attention have been identified to support the construct validity of the MMSE as a measure of cognitive mental state in patients (Jones & Gallo, 2000). The MMSE has significant correlates with the Barthel Index (Mahoney & Barthel, 1965) assessing activities of daily living, the Montgomery Asberg Depression Rating Scale (MADRS) (Montgomery & Asberg, 1979) and the Zung Depression Scale (Zung, 1965; Agrell and Dehlin (2000).

b. Reliability of the Mini-Mental State Examination

The internal consistency of the MMSE was reported to range from poor to excellent (alpha = 0.54 to 0.96) (Tombaugh & McIntyre, 1992). McDowell, Kristjansson, Hill and Hebert (1997) examined the internal consistency of the MMSE used as a screening test for cognitive impairment and dementia. The authors noted that the internal consistency of the MMSE was adequate (alpha = 0.78) (McDowell, Kristjansson, Hill and Hebert, 1997). Tombaugh and McIntyre (1992) report that

twenty-four out of thirty studies reported excellent test-retest reliability (r > 0.75) for the MMSE.

2.7.4. Assessment of the effects of treatment on quality of life

Few researchers have evaluated the long-term maintenance of improvements produced by motor, perceptual and cognitive rehabilitation. It is strongly recommended that outcome measures used in both the clinical and research setting should assess the specific intended effects of visual therapy to evaluate realistically the rehabilitation programme's effectiveness. These measures should reflect changes in impairment level, performance of everyday activities in the individual's home and community, measures of subjective well-being, and quality of life (Cicerone et al, 2000; Bowen & Lincoln, 2007; Das & Huxlin, 2010; Martin & Huxlin, 2010).

Visual impairments post-stroke may negatively affect the overall rehabilitation process, including motor-, perceptual- and cognitive therapy, by producing visual discomfort and possible loss of visual efficiency, thus affecting an individual's quality of life (Brown et al, 2003; Ciuffreda et al, 2007).

Outcome measure were selected to assess the effect of visual scanning exercises integrated with task-specific activities received by participants from Group 1 versus participants from Group 2 that received task-specific activities alone on participants that presented with unilateral spatial inattention, visual-spatial disorders and visual-constructive disorders post-stroke's **quality of life** measured with the **Stroke Impact**

Scale Version 3.0 and the **Walking ability questionnaire** eight (8), twelve (12), sixteen (16) and twenty (20) weeks after rehabilitation has been terminated.

(1)   Stroke Impact Scale Version 3.0 - Addendum 9

The Stroke Impact Scale Version 3.0 is a self-report, health status measure assessing multidimensional functional outcomes in patients who have sustained a stroke. The scale is applicable in both the clinical and research setting (Bode, Lai & Perera, 2003b).

a.   Validity and reliability of the Stroke Impact Scale

The stroke-specific outcome measure is valid, reliable and sensitive to change (Duncan, Wallace, Lai, Johnson, Embretson & Laster, 1999; Edwards & O'Connell, 2003). The test-retest reliability was calculated using intraclass correlation coefficients (ICC) that ranged from adequate to excellent (ICC = 0.7 to 0.92) (Duncan et al, 1999). The Barthel Index had an excellent correlation with the SIS ADL domain (r = 0.72) and the SIS Mobility domain (r = 0.69) (Duncan et al, 2002a).

(2) The walking ability questionnaire – Addendum 10

The intervention utilised in this trial consisted of visual scanning exercises integrated with task-orientated activities aimed at improving postural control in order to optimise functional movement post-stroke, promoting independence in ADL in and around the house, in the work environment, community, and recreational environment (Van Vliet, Lincoln & Foxall, 2005; Langhorne et al, 2009).

The questionnaire assesses the social limitations resulting from decreased walking ability in patients who have sustained a stroke (Perry, Garrett, Gronley & Mulroy, 1995:982). Although this questionnaire "offers a quantitative method of relating the social disadvantage of stroke patients to the impairment and disability sustained", no studies that assessed the walking ability questionnaire's reliability and validity have been published. Although the outcome measures' reliability and validity have not been published, it is essential to include these in the study because the test assesses the patient's functional ability on participation level by means of the individual's self-reported ability to mobilise in and around the house, in the work environment, community, and recreational environment.

2.7.5. Assessment of the effects of treatment on anxiety and depression

(1) Hospital Anxiety and Depression Scale – Addendum 11

Evidence indicates that depression and anxiety associated with stroke and visual impairment leads to decreased functional independence in ADL and a significantly poorer quality of life (Brown et al, 2003; Jones & Shinton, 2006). Difficulty with performing functional tasks and incompletion of everyday tasks are a result of motor impairment, inadequate perceptual and cognitive functioning due to a disorder of visual efficiency processes and visual-information processing, which may lead to increased anxiety and depression in patients who sustained a stroke (Chaikin, 2007). Successful and efficient performance of everyday activities in the individual's home and community contribute to a patient's subjective well-being and quality of life (Ccerone et al, 2000; Bowen & Lincoln, 2007; Das & Huxlin, 2010; Martin & Huxlin, 2010). Visual ability has been shown to contribute to the patient's level of satisfaction with life following stroke.

The Hospital Anxiety and Depression Scale was developed by Snaith and Zigmond (1983) to identify the presence of anxiety and/or depression in participants that were hospitalised. The Hospital Anxiety and Depression Scale is a valid and reliable tool for the identification and quantification of depression and anxiety post-stroke. The interpretation of the anxiety and depression subscales of the Hospital Anxiety and Depression Scale is displayed in Table 2.14.

Table 2.14. Interpretation of the anxiety and depression subscales of the Hospital Anxiety and Depression Scale (Snaith & Zigmond, 1983)

Score	Anxiety subscale
0 - 7	Normal range
8 - 10	Presence of the state of anxiety
≥ 11	Probable presence of a mood disorder
Score	Depression subscale
0 – 7	Normal range
8 – 10	Presence of the state of depression
≥ 11	Probable presence of a mood disorder

a. Validity and reliability of the Hospital Anxiety and Depression Scale

The HADS presents with excellent correlations with the Beck Depression Inventory (BDI) ($r = 0.61$ to 0.83). Correlation between the General Health Questionnaire, the Clinical Anxiety Scale and the HADS ranged from adequate to excellent ($r = 0.50$ to 0.68) and ($r = 0.69$ to 0.75) respectively. The HADS presents with an excellent internal consistency with a Cronbach's alpha = 0.85 (Aben, Verhey, Lousberg, Lodder, and Honig, 2002).

2.8. Selection criteria

Participants in the study were matched and allocated to the control and experimental groups prior to the study based on their functional activity level as measured on the Stroke Activity Scale (SAS) to ensure that participants in the two groups were comparable with regard to their functional activity level.

(1)   Stroke Activity Scale – Addendum 12

The SAS was developed to assess motor function in participants who had sustained a stroke (Horgan et al, 2006). Motor function on the SAS is assessed by five (5) subscales assessing (i) getting out of bed on the unaffected side; (ii) static and dynamic sitting balance; (iii) sitting to standing; (iv) stepping and walking; (v) bringing a glass to the mouth with arm supported on a table. The results give an account of the assessment of the five (5) subscales of the SAS. The SAS was also administered weekly over the four-week intervention period as well as eight (8), twelve (12), sixteen (16) and twenty (20) weeks after rehabilitation has been terminated.

   a. Validity and reliability of the Stroke Activity Scale

The SAS has an excellent correlation with the Modified Motor Assessment Scale (MMAS) (Pearson's correlation coefficient r = 0.91). The SAS is significantly quicker to complete than the MMAS (2.8 minutes vs. 10.4 minutes, $p < 0.0001$) (Horgan, Cunningham, Coakley, Walsh, O'Regan & Finn, 2006).

2.9. Summary

In Chapter 2 the outcome of interventions used to address ocular and visual impairments and the result of saccadic eye movement training with visual scanning exercises on patients' functional ability, perceptual processing and cognition following a stroke were reviewed. From the literature reviewed in Chapter 2 it is clear that sufficient spontaneous recovery of an impairment of the visual system is poor or almost absent in patients post-stroke. In the absence of specific intervention that addresses ocular and visual impairments including visual-efficiency processes and visual-information processing systems, the visual deficits observed in patients after a stroke may become permanent (Kerkhoff, 2000; Nelles et al, 2001; Gilhotra et al, 2002; Linden et al, 2005, Jones & Shinton, 2006; Bouwmeester et al, 2007; Schuett et al, 2009; Das & Huxlin, 2010).

Visual and ocular impairments resulting in reduced visual perception and cognition caused by stroke lead to substantial functional disability during ADL (Kerkhoff, 2000; Nelles et al, 2009). Intensive training of saccadic eye movements can improve a patient's oculomotor strategies and visual efficiency processes following a stroke. Improved oculomotor strategies will optimise the visual system post-stroke and further improve the patient's ability to use vision in everyday life (Das & Huxlin, 2010; Teasell et al, 2010).

From the literature reviewed in Chapter 2 that assessed the effect of saccadic eye movement training with visual scanning exercises on patients' post-stroke's

functional ability, perceptual processing and cognition post-stroke, it may be summarised that:

(a) decreased visual efficiency processes, specifically impaired saccadic eye movements give rise to slower oculomotor speed, decreased control and coordination of eye movements, resulting in disruption of visual scanning and attention; and

(b) interventions that incorporate saccadic eye movement training with visual scanning techniques post-stroke improve the visual system and associated improvement in perceptual processing, cognitive function and motor behaviour (Weinberg et al, 1977; Weinberg et al, 1979; Weinberg et al, 1982; Carter et al, 1983; Young et al ,1983; Webster et al, 1984; Gordon et al, 1985; Ball et al, 1988; Gur et al, 1992; Kerkhoff et al, 1992; Pizzamiglio et al, 1992; Wagenaar et al, 1992; Kerkhoff et al, 1994; Ladavas et al, 1994; Antonucci et al, 1995; Fanthome et al, 1995; Zihl et al, 1995; Paolucci et al, 1996; Kalra et al, 1997; Wiart et al, 1997; Niemeier et al, 1998; De Sèze et al, 2001; Nelles et al, 2001; Bailey et al, 2002; Brunila et al, 2002; Ciuffreda, 2002; Pierce & Buxbaum, 2002; Cappa et al, 2003; Pambakian et al, 2004; Pizzamiglio et al, 2004; Sabel et al, 2004; Bolognini et al, 2005; Cicerone et al, 2005; Rawstron et al, 2005; Bouwmeester et al, 2007; Mueller et al, 2007; Nelles et al, 2009; Roth et al, 2009).

Limitations were highlighted in the review of studies that assessed the effects of visual therapy in patients who had suffered a stroke.

(1) The effect of intervention that addressed ocular and visual impairments was mainly assessed using paper-and-pencil tasks during visual-perceptual assessment. However, the reviewed studies did not provide an indication of change in an individual's ability to function in the complex everyday activities that are relevant to

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his or her life (Weinberg et al, 1977; Weinberg et al, 1979; Weinberg et al, 1982; Carter et al, 1983; Young et al ,1983; Webster et al, 1984; Gordon et al, 1985; Ball et al, 1988; Gur et al, 1992; Kerkhoff et al, 1992; Pizzamiglio et al, 1992; Wagenaar et al, 1992; Ladavas et al, 1994; Fanthome et al, 1995; Zihl et al, 1995; Bailey et al, 2002; Brunila et al, 2002; Ciuffreda, 2002; Pierce & Buxbaum, 2002; Cappa et al, 2003; Cicerone, 2005; Rawstron et al, 2005; Reinhard, 2005; Goh, 2007; Jobke et al, 2009; Nelles et al, 2009).

(2) Few researchers have evaluated the long-term effects of interventions that address ocular and visual impairments in patients post-stroke (Gordon et al, 1985; Ball et al, 1988; Kerkhoff et al, 1994; Niemeier, 1998; Bolognini et al, 2005).

(3) Very few researchers have evaluated whether improvements produced by visual rehabilitation were sustained on the long-term (Webster et al, 1984; Gordon et al, 1985; Ball et al, 1988; Kerkhoff et al, 1994; Nelles et al, 2001; Bolognini et al, 2005).

(4) Only a few studies have assessed the effects of re-training of the visual system on the individual's subjective well-being and quality of life (Kerkhoff et al, 1994; Nelles et al, 2001; Pambakian et al, 2004; Sabel et al, 2004; Bolognini et al, 2005; Reinhard et al, 2005; Goh, 2007; Mueller et al, 2007; Jobke et al, 2009). Kerkhoff (1994) assessed improvement in the subjective rating of the patients' *(n* = 22) perceived visual impairments. Nelles et al (2001) measured patients' *(n* = 21) independence in ADL with the use of a self-rating scale of ADL.

From the limitations identified in the review of literature in Chapter 2, three (3) main conclusions were reached. Firstly, outcome measures used in the research setting to evaluate an intervention that incorporate saccadic eye movement training with visual

scanning techniques should include assessment on body impairment level, and functional activity- and participation level.

Secondly, assessment of the intervention which aims to improve the visual system post-stroke with associated improvements in cognitive function, perceptual processing, motor function and perceived quality of life should include assessment of body impairment level, and functional activity- and participation level.

Thirdly, visual scanning training through saccadic eye movement exercises integrated into increasingly complex visual-perceptual and visual-motor tasks needed to be assessed with a matched-pair randomised controlled trial. A matched-pair randomised controlled trial would assess the extent to which visual scanning training transferred to functional ability and quality of life of patients with visual impairments following stroke.