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**DEVELOPMENT OF A CLINICAL MEASUREMENT TOOL FOR  
MEASURING VOLUNTARY EYE MOVEMENTS IN TYPICAL  
INFANTS SIX MONTHS OF AGE**

**Submitted by**

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# DEVELOPMENT OF A CLINICAL MEASUREMENT TOOL FOR MEASURING VOLUNTARY EYE MOVEMENTS IN TYPICAL INFANTS SIX MONTHS OF AGE

## DECLARATION

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I, Christina Elizabeth Scholtz, student number 18382488 hereby declare that this thesis, "Development of a clinical measurement tool for measuring voluntary eye movements in typical infants six months of age" is submitted in accordance with the requirements for the Philosophiae Doctor degree in Occupational Therapy at University of Pretoria.

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**14 October 2022**

# ETHICS STATEMENT

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The author, Christina Elizabeth Scholtz, whose name appears on the title page of this dissertation, has obtained, for the research described in this work, the applicable research ethics approval.

The author declares that she has observed the ethical standards required in terms of the University of Pretoria's Code of ethics for researchers and the Policy guidelines for responsible research.

Ethics Number: ECUP no. 614/2018

# DEDICATION TO

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**My parents, in loving memory**

“Never forget that in whatever you are putting back together, the most significant restoration is what God is doing in you”

(Anonymous)

# ACKNOWLEDGEMENTS

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My sincere thanks and gratitude to the following significant influences in my life:

God Almighty, my pillar of strength.

I also dedicate my work to family members who have supported me throughout the process.

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# ABSTRACT

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**Key terms:** voluntary eye movements, neurology of eye movements, developing visual brain, functional vision and visual function

## INTRODUCTION

Occupational therapy is an essential service in early childhood intervention but does not yet fully understand the impact of the child's neuro-visual plasticity on function. Voluntary eye movements are part of visual functioning, which affects all performance areas. The visual brain is highly neuro-plastic during early infancy. The maturation of visual functions depends on the typical goal-directed visual experiences in a critical period of development.

Development of visual function processes at different rates during the post-natal period including visual acuity, contrast sensitivity and visual fields. The primary visual cortex receives visual information from the eyes and is then further processed onto the primary visual cortex for contrast, colour, disparity, direction, speed and orientation for perception. Vision related activities that represent functional vision are not only refined by the retinogeniculate projections but also the extrastriate cortex that encompasses multiple functional areas.

The post-natal development of the visual cortex, therefore, requires visual experiences during goal-directed participation. Vision for perception and vision for action provide a useful framework for understanding the functional organization of the human visual system. Perception and action depend on clear, stable, single vision and adequate control of voluntary eye movements, to convey the signals for processing. It was thus recommended to develop a clinical measurement tool for assessing voluntary eye movements in infants 6-to-7-months of age, as the maturation of visual processing depends on eye movements and visual experience in this age period. The researcher developed the voluntary eye movement measurement tool in infants 6-to-7-months of age to measure functional vision for participation. Voluntary eye movements are the foundation to process visual information efficiently for recognition, memory, organized purposeful actions, and attention on an ever-changing environment in all cultures to promote communication, social interaction, near task work, mobility and orientation. Each

item of the voluntary eye movement measurement tool is developed and designed for related activity performances.

The 4 domains are functional vision for participation, gaze holding, gaze shifting and attention. The aim of the study was to develop a clinical measurement tool for measuring voluntary eye movements in typical 6-to-7-months-old infants.

## **OBJECTIVES AND RESEARCH METHODS**

A systematic eight-step process was followed to develop the voluntary eye movement measurement tool. The aim of the study was achieved by four objectives. Quantitative and qualitative research approaches were followed.

Construct analysis and theoretical validation were used to identify and select material to operationalize the construct. Processes of inductive and deductive reasoning contributed to the generation of the domains, sub-domains and measurable items. Theory on scale construction informed the final construction of the tool. Content validity index was determined where relevant. A pilot study confirmed that the voluntary eye movement measurement tool reflected a typical developed 6-to-7-months-old infant's capability for using voluntary eye movements in a naturalistic interaction with persons, objects or the environment.

Objective one was to identify, define and analyse the construct of voluntary eye movements in 6-to-7-months-old infants by means of a theoretical exploration of literature, reviewing existing voluntary eye movements instruments/tools in children, personal communication with authors/publisher consultation with experts and the researcher's clinical experience.

In objective two the voluntary eye movement measurement tool was constructed by observing voluntary eye movements performed during social interactions, near-tasks, mobility and orientation activities with attention as identified and defined in objective one, followed by scaling the steps for each item that reflected the quality of performance that was graded on a 3-point rating scale. Furthermore, the administrative user manual, administration procedures, outcomes, scoring criteria and scoring sheet were developed and designed.

The validity of the voluntary eye movement measurement tool was evaluated in objective three by using the content validity index quantified into a validity coefficient index. The study sample for this objective was obtained from experts in the paediatric neurology field of ophthalmology, optometry and occupational therapy. The expert panellist rated the voluntary eye movement measurement tool by using the content validity index to scale the: relevance of items for 6-to-7-months-old infants, the developed rating scale, user's manual, administration and the scoring sheet. The content validity was determined to be extremely high.

The fourth objective was to pilot the voluntary eye movement measurement tool. The defined 4 domains, 5 sub-domains and 26 items generated for the voluntary eye movement measurement tool reflected the 6-to-7-months-old infant's capability for using voluntary eye movements in a naturalistic interaction with persons, objects or environment.

### **SIGNIFICANCE OF THE STUDY**

The voluntary eye movement measurement tool provides an opportunity for occupational therapists to measure voluntary eye movements that relate to visual performances for development of perception and action. This tool will allow occupational therapists practicing in early intervention, to identify, adapt and control the visual inputs that the infant constantly receives from the environment to enhance participation and performance for development in all aspects of life. This will also provide the opportunity for multidisciplinary, holistic management strategies.

# CONCEPT CLARIFICATION & DEFINITIONS

---

## **Amblyopia**

Impaired vision in one or both eyes, with no anatomical cause, due to impaired development of vision as a sequel to untreated optical (refractive) error, impaired image formation due to an eye disorder such as cataract, or impaired eye alignment (strabismus). Also known as lazy eye.

## **Atypical eye movements**

The angle of gaze is unsteady without gaze holding and shifting upon moving and stationary targets during action-perceptual activities.

## **Cerebral visual impairment**

Cerebral visual impairment is an impairment due to damage or disorder of the visual pathways and visual centres in the brain, including pathways serving visual perception, cognition and visual guidance of movement.

## **Contrast sensitivity**

Contrast sensitivity tells us about the quality of the available vision. Problems associated with mobility and reduced ability to recognise faces and objects which are common after brain injury have been found to be associated with contrast sensitivity problems.

## **Esophoria**

A condition in which the eyes have a tendency to turn in when fusion is disrupted, but the person is able to control this tendency.

## **Esotropia**

A condition in which the eyes turn in under binocular viewing conditions and the person is unable to control this tendency.

## **Exophoria**

A condition the eyes have a tendency to turn out when fusion is disrupted, but the person is able to control this tendency.

## **Exotropia**

A condition in which the eyes turn out under binocular viewing conditions and the person is unable to control this tendency.

## **Regulatory disorder**

Regulatory disorder is defined by persistent symptoms that interfere with adaptive functioning. Regulatory disorders involve differences in responsiveness to sensations, in processing sensations, and in motor planning and include fussiness, irritability, lousy crying, difficult to calm and escalating quickly from a pleasant mood to an intense cry.

## **Functional vision**

Describes how an infant functions in vision-related tasks, such as communication, social interaction and mobility. It describes how a person functions on tasks that involve multiple parameters and are based on response characteristics.

## **Radial palmar grasp**

An immature grasp in which the index and middle fingers and thumb press an object into the palm.

## **Self-regulation**

It is the internal capacity to tolerate sensory stimulation from the environment and others. It involves capacity to modulate the intensity of arousal while remaining engaged in the interaction or activity.

## **Typical**

The term typical in the context of this study can be defined as a behaviour with complexity and variability for a specific age range.

## **Typical voluntary eye movement (Related to 6-to-7-months-old infants)**

Voluntary eye movements for 6-to-7-months-old infants are the foundation to process functional visual information efficiently for perception and cognition, memory, organized purposeful actions, and attention on an ever-changing environment in all cultures for all ages to promote communication/social interaction, near task work, and mobility/orientation.

## **Visual function**

How the eye and the basic visual system function in terms of threshold performances for various stimulus parameters that are tested one at a time such as acuity, visual field and contrast sensitivity.

## **Visual dysfunction**

This term is used for atypical functional vision caused by deficits of perception, cognition, action or attention. Perceptual and cognitive deficits can cause visual dysfunction.

## **Visual impairment**

Visual impairment describes a lack of loss of one or more visual functions and can be at an ocular level called ocular visual impairment. This can be on an ocular motor level at brain levels.

## **Visual perception**

Visual perception is the ability to interpret the immediate environment by processing incoming information from visible light that is sent from the eyes to the brain.

## **Visual system**

The network that produces sight, including both eyes and the brain.

### **Voluntary eye movements**

Voluntary eye movements are responsible for localizing targets onto the fovea, the most sensitive part of the retina. Because foveal vision is the clearest, we move our eyes to ensure the image of regard falls on the fovea for purposeful goal-directed actions.

### **Quiet alert state**

This is the state in which infants present with a bright look, focus on visual or auditory stimuli with minimal motor activity.

# LIST OF ABBREVIATIONS

AIP	Anterior intraparietal cortex
ASQ-3	Ages and Stages Questionnaire
AT	Attention task
AVT	Audio-visual task
CNS	Central nervous system
CP	Cerebral palsy
CS	Contrast sensitivity
CVF	Central visual field
CVI	Cerebral visual impairment
CVi	Content validity index
Deoxy-HB	Deoxyhemoglobin
DOB	Date of birth
DST	Dynamic system theory
EEG	Electroencephalogram
EOM	Extraocular muscle
EOMs	Extraocular muscles
ERC	Ethical research committee
ERPs	Event-related potentials
FSP	Fixation shift paradigm
FT	Fixation task
f-MRI	Functional magnetic resonance imaging
f-NIRS	Functional near-infrared spectroscopy
FEF	Frontal eye field
GP	Gaze pursuit
GF	Gaze following
ICF	International Classification of Functioning, Disability and Health
ICF-CY	International Classification of Functioning, Disability and Health, Children and & Youth Version
IO	Inferior oblique
IR	Inferior rectus
IVH	Intraventricular haemorrhage
JA	Joint attention
LIP	Lateral intraparietal area
LR	Lateral rectus
MEG	Magnetoencephalogram
MeSH	Medical subject headings
MLF	Medial longitudinal fasciculus
MR	Medial rectus
mPFC	Dorsomedial prefrontal cortex
MRI	Magnetic resonance imaging
NDT	Neuro-developmental treatment/therapy
NGST	Neuronal group selection theory
NI	Neural integrator
NIRS	Near-infrared spectroscopy

nm	Nanometers
NSIR	Near-infrared spectroscopy
OKN	Optokinetic nystagmus
OT	Occupational therapist
OTs	Occupational therapists
Oxy-HB	Oxyhemoglobin
PCG	Parent/caregiver/guardian
PCGs	Parents/caregivers/guardians
PFC	Prefrontal cortex
PFV	Peripheral visual field
PMVr	Ventral premotor cortex (F5)
PPRF	Paramedian pontine reticular formation
RDS	Respiratory distress syndrome
REC	Research ethical committee
riMLF	Rostral interstitial nucleus of the medial longitudinal fasciculus
R-IPFC	Right dorsolateral prefrontal cortex
ROP	Retinopathy of prematurity
SC	Superior colliculus
SCi	Intermediate layer of superior colliculus
SCs	Superficial layer of superior colliculus
SEF	Supplementary eye fields
SNr	Substantia nigra pars reticulata
SO	Superior oblique
SPEM	Smooth pursuit eye movements
SR	Superior rectus
STS	Superior temporal sulcus
Total-Hb	Total hemoglobin
UK	United Kingdom
V1	Primary visual cortex
VA	Visual acuity
VEM	Voluntary eye movements
VEMMT	Voluntary eye movement measurement tool
VF	Visual field
VOR	Vestibular ocular response
	<b>ABBREVIATIONS FOR TIME, METRIC AND AGE</b>
2 seconds	2 s
5 minutes	5 min
Eight centimeters	8 cm
Six-month-old	6-month-old
Six-to-seven-months-old infants	6-to-7-months-old infants

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# CHAPTER 1

## INTRODUCTION

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### 1.1 INTRODUCTION

The researcher's clinical reasoning for conducting this study was guided by literature. Therefore, a clinical measurement tool for voluntary eye movements (VEMs) in typical six-months-old infants (6-months-old) was developed. However, as the pilot study sample included infants whose ages ranged from 6-months, 1 day to 6 months, 30/31 days, the term 6-to-7-months-old infants will be used hereon. The foundation for this study is the theoretical knowledge and practical experiences the researcher had obtained in a paediatric neuro-developmental clinical based setting for the last 40 years.

In recent decades, the severity of disability levels among premature infants, born at a very low birthweight, with visual impairments and other disabilities have notably increased. This increase may result from improvement in survival rates at the earliest gestational ages (Stockall et al., 2020). However, these premature infants in particular, are at risk for retinopathy of prematurity, visual impairment and visual dysfunction caused by damage to the brain (Pascal et al., 2018). The infant's visual functions are not always processed simultaneously with other sensory and motor demands that compete for attention, when working with infants at risk due to peri-, pre- or post-term insults (Leung et al., 2018). Any infant at risk with or without neurological insult requires continued monitoring of the developmental characteristics (Wickremasinghe et al., 2013).

Neuroplasticity is a complex process and is fundamental for early intervention to optimize neural connectivity for learning and to prevent complications (Raz & Levin, 2017). The enhancement of the plasticity remains under construction well into adolescence due to the organization of networks of neuronal synapses as well as white matter pathways (Tsuneishi & Casaer, 1997; Federer & Zylberberg, 2018). Synaptic plasticity mechanisms govern cortical circuitry which is fine-tuned by sensory experiences in early life (McCoy et al., 2009). The visual synaptic

mechanism is shaped early in development and is the most functional diverse mechanism in the brain (Tinelli et al., 2020).

There are a number of visual function features that are commonly considered in the context of a neurological insult. In addition to visual acuity (VA), contrast sensitivity (CS) and visual field (VF) impairments, many infants with a neurological insult have additional dysfunction in visual processing and atypical ocular motility (Tinelli et al., 2020). Fazzi et al., (2012) found that the most compromised visual items in their sample were ocular motricity such as fixation, smooth pursuit eye movements, saccades and VA in children with cerebral palsy.

An infant's potential for optimal visual functioning depends on the dynamic developmental systems (Groffman, 2006; Spencer et al., 2012) fully developed by as early as 6-month of age, before other functions such as the ability to walk and talk. Therefore, functional vision is the necessary precursor to the proper development of other bodily and mental functions for goal-directed activities and participation related to social abilities (Dusing, 2016). According to Dusing (2016) an inter-relationship exists between an infant's postural complexity, generalized movement, sensory-motor experiences for higher cognitive functioning and attention in the early development both for infants who develop typically and those at risk for disabilities. Therefore, it is critical to understand the extent of the visual abilities, specifically eye movements, in infancy. The terms ocular motility (Scheiman, 2011), oculomotor control (Dutton, 2002) and eye movements (Braddick & Atkinson, 2011) are similar in its neurophysiology functions. The voluntary control of eye movements (voluntary eye movements) is the way the brain transforms sensory signals into motor commands (Leigh & Zee, 2000) for purposeful goal-directed participation.

Therefore, for the development of perception and action, the neural control of VEMs is organized to optimize performances (Gallivan et al., 2011). Perception and action require the neural control of VEMs for visual signals conveyed to the brain to be processed differently for communication, orientation in space, activities of daily living and sustained demanding visual tasks (Hyvärinen, 2010).

Understanding the interaction of VEMs activities or limitations with related single-multisystem integrities and/or impairments through careful and ongoing analysis is foundational within the practice of occupational therapy. Limited information to measure VEMs was found in the clinical setting and therefore the need was identified to develop a clinical measurement tool for measuring VEMs in typical 6-to-7 months-old infants.

## **1.2 BACKGROUND**

The (re)habilitation, and promotion of health and wellness for clients with disability and non-disability related needs arguably represents the largest area of occupational therapy practice (Boop et al., 2020). Occupational therapy is focused on helping individuals with any illness, injury, or deficit in occupational performance that is not specified in the other practice areas and improves their participation in activities of daily living (Preissner, 2010). The purpose of an occupational therapist (OT) is to increase the individual's participation and activity in the context of an occupation/s (Boop et al., 2020).

### **1.2.1 The role of the occupational therapist**

The role of an OT is to promote an individual's independence, mastery and sense of self-worth in physical, emotional and psychosocial development and behaviour through the organization of sensory information (Case-Smith, 2010). Sensory processing is a reflection of brain activity (Pfeuty et al., 2008). It refers to the ability to take in information through the senses and to organize and interpret that information, making meaningful response that can assist an infant with self-calming, going to sleep or maintaining alert attention (Harvey & Macklem, 2009).

As this process unfolds in infancy, the developing infant begins to attach meaning to the stream of sensations experienced (Greenspan et al., 1998; Greenspan & Wieder, 2008). These experiences then support the development of sensory processing which will be used to analyze new information, develop skills and regulate behaviour (Dusing, 2016). The infant's unique motor behaviours are the result of input from multiple systems that interact in dynamic ways to both facilitate and constrain movement. Occupational therapists have developed and used theory and models of practice to explain the interaction of person, occupation and

environment (Baptiste, 2017). The theories, models and approaches used for this research are presented.

### **1.2.2 Theories and frameworks: guiding the clinician's practice**

According to the dynamic systems theory (DST), the result of many interactions of subsystems emerges in sensory-motor behaviours in infants in a task context (Smith & Thelen, 2003). An infant's motivation, defined by a goal, and guided by perception and planning is identified as the action perception theory (Von Hofsten, 2004). The emphasis on the interaction between the developing central nervous system (CNS) and the environment is clear in the developmental theory. An intact matured CNS contributes to the development and coordination of complex movements required for active exploration in an environment (Bilbao et al., 2003). Translation of the concepts of neuronal group selection theory (NGST) to motor development behaviours implies that motor development is characterized by two phases of variation. The primary variability is not geared to external conditions, but the secondary variability motor performance can be adapted efficiently to specific situations (Hadders-Algra, 2000). In both forms of variability selection on the basis of afferent information plays a significant role. Atypical development due to a lesion of the brain at early age is characterized by limited repertoire of motor strategies and difficulties in adaptation of motor behavior to task specific conditions (Hadders-Algra, 2002). Variation is crucial for typical development.

Clinical expertise with literature describes the difficulties experienced by the child with cerebral palsy (CP) in a previous study done by the researcher (Scholtz, et al., 2013). A strong significant association between eye movements and postural alignment were established. The results of the study indicated children with CP have limited repertoires of motor strategies influencing postural alignment that affect eye movements. On the other hand, CP children's difficulty moving their eyes efficiently with variation may also affect the postural alignment. Voluntary eye movements and posture are essential for activity participation in the occupational therapy process.

### **1.2.3 Relationship between posture, movement and sensory processing**

With any type of impairment, the sensory processing of afferent information will be interfered with or will be distorted (Eliasson, 2009). Neurologically challenged

individuals are often unable to appropriately detect, recognize (identify) or discriminate single-sensory or multisensory information which can result in significant deficits in movement or postural orientation influencing purposeful activities and functional performances (Foley & Greaves, 2010).

According to a review (Chu, 2017), sensory information affects postural control in children with CP. It is stated that the child with CP is less responsive to sensory input influencing postural adjustments during sensory perturbations. During sensory conflicts they exhibit less postural stability. Although certain studies (Corbetta & Snapp-Childs, 2009; Weimer et al., 2001; Cabral et al., 2016) have examined the role of sensory changes on postural control in CP and developmental delay in children, there is no evidence that they have conducted a comprehensive structured evaluation of their sensory integrative capacities specifically with respect to eye movements.

### **1.3 VISION IN THE TYPICAL INFANT**

Vision is considered the most influential sense in humans (Arndt et al., 2008). The visual world occupies a major portion of our attention and cognition, however vision is often taken for granted and we are unaware of the complex neural interactions involved in visual processing (Raz & Levin, 2017). Consequently, we are often unaware of the pivotal role that vision plays when walking down a busy street, comparing faces of thousands and stopping to greet a person you recognize. Visual sensation helps to drive the movement system, map the environmental space, and orient the body within the spatial array (Orban et al., 1996) (Barthel & Cayo, 2016).

The visual system is mature at birth relatively to other sensory systems, thus any pathology which impairs visual development has a long-standing impact overall on the development and visual processing functions in particular (Pel et al., 2016). Therefore, attention to the neuro-visual plasticity is paramount in the management of childhood development (McCoy et al., 2009). Before an infant can move with any predictability, their vision begins to explore the persons, toys, room, furniture and the changing light that make up the nearby world (Lane, 2005). The information that the infant receives through the eyes is matched with the tactile system as the motor system becomes more competent (Atkinson & Braddick, 2012). Highly specific visual cortical and sub-cortical connections depend on appropriate typical age

visual-motor related activities with experience (Hyvärinen, 2010). Visual development in the first year of life includes eye movement and brain networks. The networking process involves sensory-visual input with other systems for visuo-motor control, cognition and selective attention (Braddick & Atkinson, 2011). Vision for the perception of the world requires that incoming visual signals need to be compared to long-term detailed visual memories to facilitate understanding of what is being seen. In contrast, vision for the control of action must reflect the real geometry of the outside world which can change on a moment-to moment basis (Dutton, 1994). Vision for perception and vision for action provide a useful framework for understanding the functional organization of the human visual system. Perception and action depend on clear, stable, single vision, the voluntary control of eye movements, to convey the signals for processing. Before a discussion of voluntary eye movement can begin, it is important to discuss how the terms functional vision and visual functioning is used in this research since definitions for and interpretations of, these terms vary and are further discussed in Chapter 2.

### **1.3.1 Visual functions**

Visual functions such as VA, VF and CS refer to, and describe, how the eye and visual system function, with measures taken at the eye or organ level, are usually performed in a static, controlled environment (Colenbrander, 2010). These threshold measures of VA, VF and CS were measured quantitatively as part of the inclusion criteria for this research study and is discussed in Chapter 3.

In ophthalmology, the measurement of visual functions is well developed and it focuses on the prevention and treatment of eye disease (Francisco, 2003). Psychophysical measurement of visual function has been standardised for infants 6-months of age and includes the assessment of VA, VF and CS (Teller et al., 2005). The method of forced-choice preferential looking, originally developed for the purposes of basic research, has gained wide popularity (Stolk et al., 2009). This method has proven to be useful when testing infants with a variety of neurological intellectual disability and ophthalmological disorders (Allen et al., 1996). With psychophysical testing, interpretation of a child's ability to see is dependent upon their motor eye movement response. An infant is given a choice of looking at a homogeneous target or at a target with gratings (Suttle, 2001). When the infant

appears to see by shifting his/her gaze to the target with gratings, finer grating sizes are presented (Wattam-Bell, 1996) to threshold their activity and thereby their VA. Grating detection acuity depends on VEMs. Measurement of detection acuity can be used in examination of infants as soon as the infant can fixate, hold and/or shift their gaze, purposefully on objects.

Contrast sensitivity which refers to an individual's ability to distinguish an object from its background under varying levels of contrast as in the visual environment has been shown to be better related to the performance of everyday activities and therefore may be more important than just good VA (Dutton, 2013). According to Hyvärinen (2013) many studies have been performed on adults and are not applicable to infants. It has been suggested that measuring CS may help in the diagnoses of certain eye conditions such as strabismus, optic nerve neuritis or glaucoma.

Leat et al., (2009) used preferential looking techniques and found the most rapid development of CS to be in the first 6-months of life. Mr Happy is a test to assess CS. The response of the infant is to choose the card with the face by shifting his/her gaze as long as they are able to see it. Every card has a different contrast level (Bosworth & Dobkins, 2009) and a strong correlation was found between visual evoked potential assessments and forced preferential looking indicating that the cards used for CS are an ideal target to be used for this assessment. Hyvärinen (2009) suggests making three CS measurements in infants at 6-months of age, one at the highest contrast levels and the other two at lower contrast levels. As CS relates to VA, the same distance can be used as for the acuity testing. Measurement of CS can be used in examination of infants as soon as the infant can fixate and shift their gaze purposefully on objects.

Visual field is the area of space visible to the eyes when looking straight ahead. The most usual technique in measuring the size of the visual field is the confrontation method technique in which the infant is encouraged to look straight ahead. A stimulus is then moved forward from behind the infant and the tester observes when the infant notices the stimulus by shifting gaze towards the target with or without head movement (Stolk et al., 2009). Gaze holding and gaze shifting are important for the examination of visual functions.

Francisco (2003) states that even a person with 20/20 acuity with a normal scope of CS and VF, or so called “perfect sight”, may be unable to find his own key on the table in front of him. Thus, sight relates to static measurements of acuity which quantifies certain aspects of our vision, but it does not directly relate to how we use our vision in function.

Infants at risk due to prematurity without ophthalmological impairments or structured brain damage, may have delays in visual modalities, such as eye movements due to deficits in neuronal connectivity in visual pathways at a micro-structural level (Pel et al., 2016). Deficits in visual functions are visual impairments for e.g., VA impairment, VF impairment and CS impairment. If visual function is impaired owing to higher order perceptual or cognitive impairments the term visual dysfunction is applied (Colenbrander, 2010).

### **1.3.2 Functional vision**

Functional vision describes how an individual functions in vision-related tasks with the emphasis on performances such as communication, social interaction, orientation and mobility that involve multiple parameters and are based on response characteristics (Colenbrander, 2010). Francisco (2003) states that the measurement of individual visual skills and abilities, that represents functional vision, lags far behind. Functional vision describes the manner in which a person uses available visual information and visual abilities in the daily life situations (Colenbrander, 2010). Voluntary gaze holding and shifting are the pre-requisites for detection, discrimination and recognition that leads to processing for action and perception. Visual information arrives via the retinocalcarine pathway into the primary visual cortex and is processed in two main streams of specific functions that also have close connections to visual attention and the ocular motor areas in the frontal, parietal lobe, premotor cortex and subcortical tectal pathways (Hyvärinen, 2008). The emphasis in this study is the skill use of VEMs for a purposeful goal-directed activity. The term visual dysfunction describes a failure of functional vision, owing to an abnormal mode of functioning of the higher cerebral centres that process visual information (Colenbrander, 2010).

## 1.4 VOLUNTARY EYE MOVEMENTS

The study of eye movements is a source of valuable information to both scientists and clinicians. To the neurobiologist, the study of the control of eye movements provides a unique opportunity to understand the workings of the brain (Ismail et al., 2017). Voluntary eye movements are responsible for localizing targets onto the fovea, the most sensitive part of the retina. The movements of the eyes ensure that a clear image falls on the fovea (Carpenter & Batton, 1980). Voluntary eye movements are the foundation to process visual information efficiently for recognition, memory, organized purposeful actions, and attention on an ever-changing environment in all cultures for all ages to promote communication, social interaction, activities of daily living, near task work, mobility and orientation (Hyvärinen, 2008). Voluntary eye movements are task dependent (Yeomans et al., 2021).

Atypical eye movement are among the most common visual dysfunction found in the brain-injured population and with neurodevelopmental disorders (Ciuffreda et al., 2008; Van Herwegen, 2015). Van Herwegen (2015) recommended further studies in eye movements in infancy onward across development. The methods available for measuring eye movements in infants are not well described in the literature. At present the magnetic search coil technique and electro oculography is generally regarded as the most reliable and versatile method for this measurement in adults (Leat et al., 2009). Atypical eye movement is when the angle of gaze is unsteady, without gaze holding and shifting upon moving and stationary targets during action-perceptual activities (Scheiman, 2011).

Maples (1995) reviewed 15 oculomotor tests with respect to the identified variables, targets, test distances, instructions and ocular conditions detectable for each test. These tests were developed mainly by the optometry discipline (with a minority developed by other disciplines). None of these tests were developed by establishing norms for a specific age group, and the youngest group tested was two years of age. The majority of screening and/or testing for eye movements is observation based (Baxstrom, 2006). No validated tool is currently available to occupational therapists for clinical measurement of eye movements.

The researcher's interest and clinical expertise in eye movements are not laboratory-based methods but rather from a practical field of knowledge. A laboratory-based method of assessing eye movement is not function orientated e.g., eye movements for communication entails that an infant has a combination of eye movements, specifically gaze holding and shifting. It also depends on whether gaze is shifted between an object and a partner's face to perhaps comment on something, ask about it or request it (Scholtz et al., 2013). This illustrates that functional, VEMs have specific purposes involving collaborative interactions between the child, their partner and the environment (Leigh & Zee, 2000). Visually guided eye movements are an essential part of vision. They determine the ability to adequately scan the environment and to fixate and follow an object of interest (Fazzi et al., 2004).

The International Classification of Functioning (ICF) should influence assessment and classification of the different forms of visual-processing disorders in children. The International Classification of Functioning, Disability and Health, Children & Youth Version (ICF-CY) (Simeonsson, 2009), stresses the assessment of functional vision, rather than the measurement of a few visual functions such as VA, CS and VF, which are used for surveys of visual impairment but are insufficient for the type of assessment required to guide (re)habilitation and education. Thus, the development of a visual measurement tool for functional VEMs in early infancy will allow clinicians to detect deviations from the typical VEMs.

Consideration of the nature of the sensory-motor processing which would seem to be needed for development, led clinicians to believe that infants need specific abilities and skills in the dynamic systems for purposeful directed actions and perception (Von Hofsten, 2004). The literature review, as part of the developmental phase for this study, emphasised the importance of VEMs as a pre-requisite of functional vision in the developing infant. Sensory-motor eye movement development is rapid and complex. The researcher identified the domains of VEMs that needed to be investigated. The difference between visual function and functional vision has been emphasized.

## 1.5 PROBLEM STATEMENT

Why clinicians do what they do, needs to be explained in an evidence-based research framework and/or clinical experience for effective treatment. A statement made by McCloskey and Prochazka (1994:74): “One can only control what you sense”, highlights the importance of sensory processing and perception for effective motor performances, participation and learning. Unidentified sensory visual processing anomalies from an early age can result in lasting developmental changes and losses in interaction with the environment which impacts multiple areas of development and a subsequent impact on families or society (Ryckman et al., 2017).

Most existing tests of vision related functioning are designed for adults (Leat et al., 2009). For infants at risk, the situation is different. Loss of vision in the adult is fundamentally different from lack of visual processing from an early age (Maino, 2012). Infants cannot verbalize their symptoms and do not follow instructions (Bodack, 2011). A better picture of functional vision has to be obtained for 6-to-7-months-old infants by using a valid and reliable clinical measurement tool for VEMs. With this tool, a history of typical sensory-motor behaviour to identify systems influencing the neuronal networking for higher cognitive functioning, thoughts, ideas and occupational participation is obtained (Eeles et al., 2013). A team-based approach is also necessary and this requires a common framework of thinking.

The development of vision in infants is a difficult field to study since the process of seeing, as well as the evaluation of this process, encompasses ocular, CNS and behavioural development (Pel et al., 2016). The literature review in Chapter 2 will give a brief overview for these constructs. Currently, no clinical measurement tool for VEMs is available in South Africa for typical 6-month-old infants, nor did a literature search reveal any other valid equivalent measurement tools for VEMs in 6-month-old infants in the clinical setting. This clinical measurement tool can therefore support infants with developmental difficulties and their families, provide a mechanistic understanding of disorders, help define prognoses, document the effects of interventions and estimating the national prevalence of developmental delays in the visual-perception and action systems (Ortibus et al., 2011; Gegenfurtner, 2016). This all led to the following research question.

## 1.6 RESEARCH QUESTION, AIMS AND OBJECTIVES

How does one develop a clinical measurement tool for measuring VEMs in typical infants 6-to-7-months of age?

### Aim:

- The aim of the study was to develop a clinical measurement tool for measuring VEMs in typical 6-to-7-months-old infants.

### Objectives:

- To identify, define and analyse the construct of VEMs in typical 6-to-7-months-old infants.
- To develop and construct the Voluntary Eye Movement Measurement Tool (VEMMT).
- To establish content validity of the VEMMT.
- To pilot the newly developed VEMMT.

## 1.7 DEFINITION OF KEY TERMS AND CONCEPTS

Table1.1 consists of the key terms for this study.

Table1.1: Definitions of the key terms

<b>KEY TERMS</b>	<b>DEFINITION</b>
<b>Atypical eye movements</b>	The angle of gaze is unsteady, without gaze holding and shifting upon moving and stationary targets during action-perceptual activities (Ciuffreda et al., 2008; Van Herwegen, 2015).
<b>Functional vision</b>	Describes how an infant function in vision-related tasks that involve multiple parameters and are based on response characteristics (Francisco, 2003).
<b>Visual dysfunction</b>	Visual dysfunction describes a failure of functional vision, owing to an abnormal mode of functioning of the higher cerebral centers that process visual information (Colenbrander, 2010).
<b>Visual function</b>	How the eye and the basic visual system function in terms of threshold performances for various stimulus parameters that are tested one at a time such as VA, CS and VF (Leat. et al., 2009).
<b>Visual impairment</b>	Visual impairment describes a lack of loss of one or more visual functions and can be at an ocular level called ocular visual impairment and at brain level cerebral visual impairment (Scheiman, 2011).
<b>Voluntary eye movement</b>	Voluntary eye movements are responsible for localizing targets onto the fovea, the most sensitive part of the retina. Because foveal vision is the clearest, we move our eyes to ensure the image of regard falls on the fovea for purposeful goal-directed actions (Hyvärinen, 2010).

## 1.8 CONTEXT / SETTING

This study was conducted in a clinical environment where patient/client care and clinical activities take place. For this study a clinical setting with overhead diffuse fluorescent light was utilized. The space and environment were cleared of all visual and auditory distracting objects/ people and noise. The infant was held, in a supportive manner, by the parent/caregiver/guardian (PCG) who sat on her/his lap with support, on an adjustable chair facing the researcher. A desk was used for most of the identified measurable items.

## 1.9 ASSUMPTIONS

The assumptions are summarized in Table 1.2.

Table 1.2: The assumptions

<b>ASSUMPTION</b>	<b>DESCRIPTION</b>
<b>Scores</b>	After the development of the VEMMT, the scores will differentiate healthy infants from infants with developmental delays.
<b>Gender and age</b>	If the developed VEMMT will show differences in performances based on age between 6-to-7-months-old infants, clinicians will have the opportunity to intervene earlier to prevent complications as well as to enhance development in all aspects of sensory-motor-cognitive development.
<b>Varying degrees of risks</b>	The two reasons for the proposed newly developed measurement tool for VEMs are firstly to identify any deviations and to make a decision about the individual infant, and secondly to evaluate the effectiveness of an intervention strategy.

## 1.10 DELINEATION

The newly developed clinical VEMMT can support infants with developmental difficulties and their families, provide a mechanistic understanding of disorders, help define prognoses, document the effects of interventions and estimate the national prevalence of developmental delays in the visual-perception and action systems.

## 1.11 SIGNIFICANCE / CONTRIBUTION

William Shakespeare (Gupton, 1999:482) once said: “The eyes are the window to your soul” but in this research study the eyes are also the window to the brain, harnessing neuroplasticity. Practising in the neuro-developmental field as an OT has led the researcher to believe that early diagnoses of possible sensory-motor perceptual processing deficits are critical for early intervention. This was recommended in the researcher’s Master’s degree thesis (Scholtz et al., 2013). According to this study no descriptive notes were identified of visual dysfunction in the child and infant with central neurological insults because of a wide range of clinical presentations in different circumstances and settings.

This research will be designed for use by health professionals who are knowledgeable regarding sensory-motor-perceptual development of infants and have experience in the examination of, and intervention for preterm and full-term high risks infants under the age of one year (corrected age for prematurity if necessary). A systematic measurement tool of VEMs for infants will allow occupational therapists (OTs), practicing in early intervention, to identify, adapt and control the visual inputs that the infant constantly receives from the environment in order to enhance participation and performances for development in all aspects of life.

The newly developed VEMMT for infants 6-to-7-months of age will assist the clinician in an early intervention clinical setting. Therefore, the key outcome of this research is to develop a measurement tool that can be used in a clinical setting to identify deviations in VEMs for further investigation and/or early therapeutic intervention options to benefit infants as a class, enhancing neuroplasticity. This will also help to inform policy makers and government in their decision on investment on early child development. Most importantly, OTs will ultimately make a contribution by accruing information to add to the body of knowledge about the profession.

It is apparent so far that, if the newly developed VEMMT can be used as an indicator of brain dysfunctions this measurement tool will be a valuable aid for early intervention programmes. This VEMMT can complement other developmental and medical assessments for early identification and referral for treatment of neuro-developmental delays and impairments (for preterm infants or those with perinatal insults contributing to their developmental vulnerability).

## **1.12 CONCEPTUAL OPERATIONAL FRAMEWORK**

The model of Miller et al., (2011) is used to develop the newly VEMMT and is presented in phases. It combines qualitative and quantitative approaches. The four phases of the study design as suggested by Miller et al., (2011) for the development of the clinical measurement tool for VEMs in infants 6-to-7-months of age, is documented in Figure 1.1.

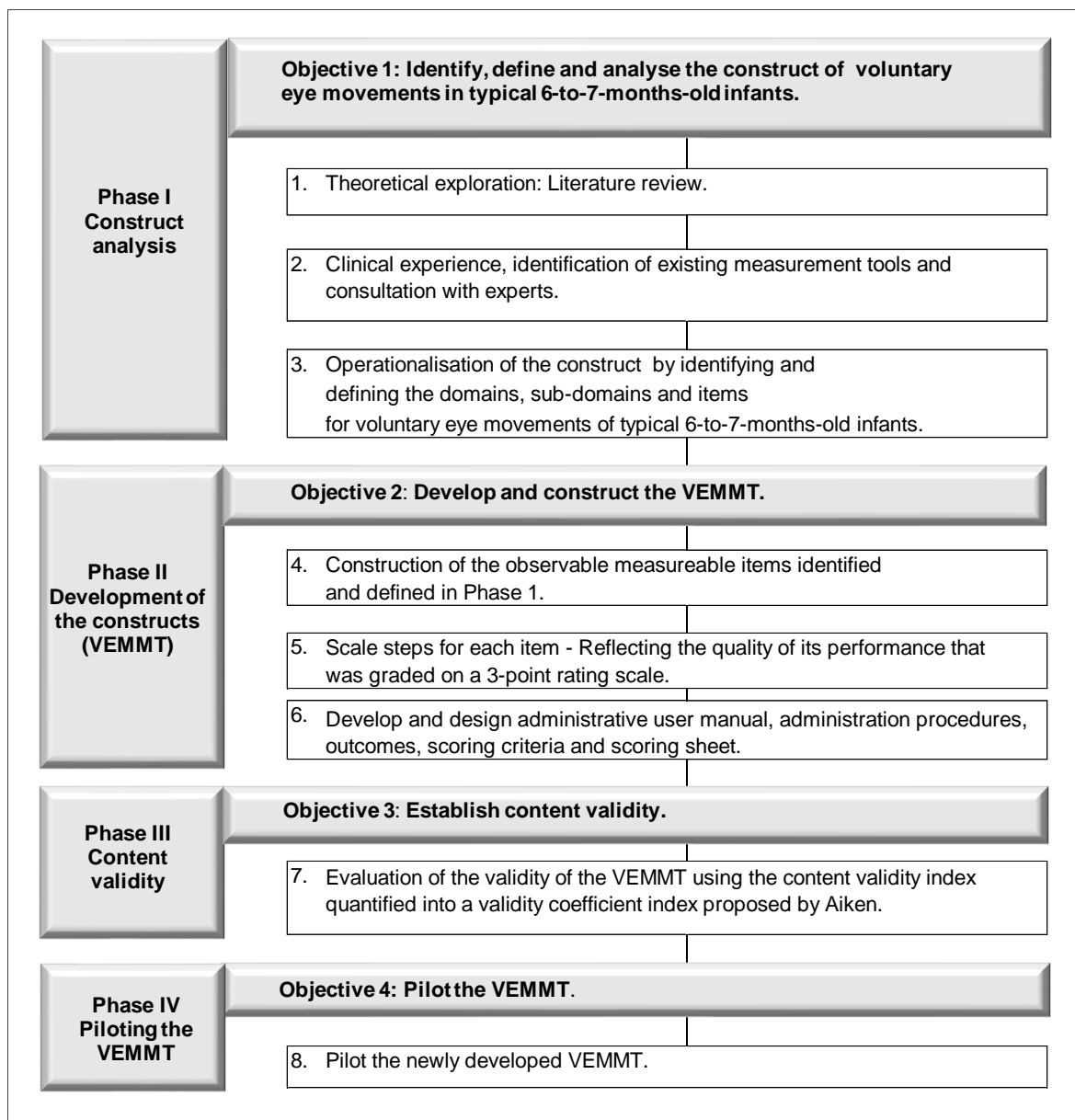


Figure 1.1: Schematic diagram of the study procedure undertaken towards the development of the VEMMT

### 1.13 ETHICAL CONSIDERATIONS

From the Ethics Committee (ECUP no. 614/2018) ethical approval for this research was obtained. A request was admitted to the ethical committee to change the size and sampling method for the pilot study due to the COVID-19 pandemic. The VEMMT is developed to measure VEMs in 6-to-7-months-old infants. The proposed amendments have been authorized by the ethical committee (Appendix A). A detailed description of the ethical aspects is described in Chapter 3.

## 1.14 OVERVIEW OF THE CHAPTERS

**Chapter 1:** *The introduction to the study:* Provides an overview of the study that has led to the problem statement, aims and objectives of this study. A summary of methodology is included with the emphasis on the value and extent of this study for OTs in future. The ethical aspects applied for this study is described in detail in Chapter 3.

**Chapter 2:** *Literature review:* Contains details of the literature reviewed in order to identify, define, and analyse the construct of the VEMMT in typical 6-months old infants. Furthermore, the literature review informed the necessary procedures and objects/ target to be used, how other systems can influence VEMs and the role of the environment.

**Chapter 3:** *Research approach and methodology:* The research methodology employed in this study is described in detail. It thus describes the ethical clearance and implementation obtained for study, description of the research design, study population, sampling, measurement instruments and methods used for collecting the data and data analysis. The procedures utilized in establishing content validity, and thereafter the testing of the newly developed VEMMT provides a conclusion to this chapter.

**Chapter 4:** *Voluntary eye movement measurement tool:* An overview of the process of developing the VEMMT is given in this chapter. The first six step processes are addressed in this chapter namely:

- To analyse the construct by identifying, defining and analysing the domains, sub-domains and items for infants 6-months of age.
- To construct the tool by observing VEMs performed during social interactions, near-task, mobility and orientation activities with attention as identified and defined that are compiled in an administrative user manual, detailed administration procedures, outcomes, scoring criteria and a scoring sheet.

**Chapter 5: *Content validity*:** This chapter represents the results of the judging panellist to determine content validity. The results are displayed and discussed in tables after the data analysis. The results indicate that the VEMMT has an extreme high content validity.

**Chapter 6: *Pilot study*:** This chapter presents the results of the pilot study. Results are displayed and discussed in tables. This chapter provides an interpretation and discussion of the results of the pilot study and conclude the results in relation to the research aim and objectives. The results obtained are further described and summarized in this chapter. The study showed that by 6-to-7-months of age the infant had developed the skill of adjusting the hand to an object, orienting and adjusting the grip based on visual clues and both upper extremities are brought together consistently. Smooth straight reaching pathway depends on the transformation of the visual space to a body-centered coordinate system. Voluntary eye movements and the organized purposeful actions are dramatic observable measurable behaviours. When compared to typically developing children VEMs and purposeful actions are observable behaviors. Findings are discussed according to the categories emerging from data. This chapter forms the basis on which the subsequent discussion, conclusions and recommendations are made.

**Chapter 7: *Conclusions and recommendations*:** This chapter discusses the value and benefits of the developed VEMMT. The researcher presents the conclusions based on the main findings. It also provides a summary of contributions, the limitations of the study and recommendations for future research.

## **1.15 CONCLUSION**

The complexity of visual and functional vision and its disorders means that a structured approach to the clinical measurement of VEMs in infants of 6-to-7-months of age is required to ensure that each aspect of dysfunction is recognised and measured for the purposes of planning early intervention. Voluntary eye movements play a central role in early development and is pivotal in the development of perception and action for participation in the daily life of an infant. Development of the CNS is not predetermined but depends on interaction with external factors and on the activity in the neural circuits.

# CHAPTER 2

## LITERATURE REVIEW

---

### 2.1 INTRODUCTION

“How do we come to know the world?” is an ancient question that philosophers, researchers, and clinicians have tried to answer for centuries. The world is a wonderful, complicated place and each one of us perceives it in our own way, learning to live in and enjoying our ever-changing world. Like all clinicians working in the neuro-developmental field, our duty of care and treatment is to help infants with neurological insult to grow and thrive. The neural control of eye movement is organized to optimize the performance of general sensory-motor-perceptual tasks allowing for exploration (Fazzi et al., 2010).

### 2.2 FUNCTIONAL VISION VERSUS VISUAL FUNCTION

The behavioural aspects of functional vision are distinct from visual function. Functional vision describes how a person functions in vision-related activities that involve multiple parameters and are based on response characteristics (Colenbrander, 2003). Voluntary eye movements and neuronal-networking allow visual information to be processed for purposeful goal-oriented activities (Bultjens et al., 2010). Therefore, the importance of this research is not to assess only eye movements per se but also rather measure voluntary eye movements (VEMs) during purposeful goal-oriented activities such as reaching for a toy or during social interaction games. Visual dysfunction describes the failure of functional vision (Colenbrander, 2003).

Based on threshold performances for various stimulus parameters that are tested one at a time such as visual acuity (VA), contrast sensitivity (CS) and visual field (VF), describe the eye- and the basic visual system function (Philip et al., 2016). Visual functions are not limited to disorders of the eyeball; among congenital defects, cerebral and/or cognitive visual impairments may exist while traditional functions such as VA are normal. In clinical practice, it has been observed that eye movements are poorly integrated, both with functional vision and visual functions. Contrast sensitivity, VF and VA mature over different time scales depending on the

particular aspect of function that is being measured (Wattam-Bell, 1991). The latter has been used as an inclusion criterion for this study.

With the improvement in perinatal care and higher survival rates in infants, the incidence of cerebral damage and brain development disorders in children have increased (Ghasia et al., 2008). Damage to the cortical and/or subcortical visual brain can impair VA, CS (visual functions), perceptual processing, cognition (functional vision) with or without VF restrictions (Dutton, 1994) and is collectively called cerebral visual impairment (CVI). Researchers (Kooiker et al., 2014; Dutton & Jacobson, 2001) defined cerebral visual impairment as an impairment due to damage or disorder of the visual pathways and visual centres in the brain, including pathways that serve visual perception, cognition and visual guidance of movement. The visual brain is the totality of brain elements serving or supporting vision that serves to map, search, give attention to recognise and interpret visual input. The visual brain provides mapping information to motor planning centres of the brain (Dutton, 2002).

Although cerebral visual impairment (CVI) can occur in the context of normal VF and VA, it can cause multiple functional problems such as impaired recognition of people, shapes, objects, communication, social interaction, orientation, difficulties in handling complex visual scenes and inaccurate visual guidance of limb function (Hoyt, 2007). Dutton (1994) defined visual perception as the ability to interpret the immediate environment by processing incoming information from visible light that is sent from the eyes to the brain.

Practicing in the neuro-developmental field as an OT has led the researcher to believe that early diagnoses of possible sensory-motor perceptual processing deficits are critical for early intervention (Scholtz et al., 2013).

A systematic voluntary eye movement measurement tool (VEMMT) for infants will allow occupational therapists (OTs), practicing in early intervention, to identify, adapt and control the visual inputs that the infant constantly receives from the environment in order to enhance participation and performances for development in all aspects of life. The literature study is to give an overview on typical VEMs development for 6-to7-months-old infants for participation in activities such as social interaction or reaching for a toy. It is important in a functional activity for infants to shift, hold or

move the eyes. Neuronal networks, attention and self-regulation will be integrated with the typical development of social interaction, communication, reaching, grasping and mobility in this chapter. The term typical in the context of this study can be defined as a behaviour with complexity and variability for a specific age range (Bly & Ariz, 1995).

## **2.3 THE ROLE OF THE OCCUPATIONAL THERAPIST IN THE EARLY INTERVENTION FIELD**

The role of an OT is to promote an individual's independence, mastery and sense of self-worth in physical, emotional and psychosocial development, as well as in behaviour, through the organization of sensory information (Case-Smith, 2010). As this process unfolds in infancy, the developing infant begins to attach meaning to the stream of sensations experienced (Greenspan et al., 1998; Greenspan & Wieder, 2008). These experiences then support the development of sensory motor processing which will be used to analyze new information, develop skills and regulate behaviour (Dusing, 2016).

The researcher's clinical experience determined the way of thinking about, observing, interpreting and handling a typical infant and an infant with neurological insult. Furthermore, the researcher recognised that typical development are age-appropriate behaviours. These behaviors arise from ongoing interaction of the neural, sensory-motor-perceptual systems and adaptations that influence the environment (Capelovitch, 2018).

In the clinical setting OTs observe, assess and treat infants as holistic. This includes postural alignment, hand function, social interaction with communication, attentional neural networking, sensory regulation with an adaptive response, all important for voluntary gaze holding and shifting in goal-directed actions for 6-to-7-months-old infants. The latter concepts will be discussed.

### **2.3.1 Postural alignment**

The ability to control the body's position in space is fundamental to everything we do, and good postural alignment, control and support is necessary while performing functional visual activities for measurement (Foley & Greaves, 2010).

Supported sitting on the mother's lap will be the most suitable position to administer the VEMMT. At 6-to-7-months of age due to increased trunk control, head control is fully developed (Bly, 2014). The infant at 6-to-7-months old can sit independently without external support (Alexander, 1993). The lateral flexion is still difficult therefore if weight is shifted laterally during sitting the baby can fall sideways. The baby can reach for toys when the trunk is supported. Hip extensors are also not fully developed and thus the infant may lean forward (Bly & Ariz, 1995). Unwanted movement of the head and body might imply an instability of the total posture mechanisms that include eye, head and body in space and therefore require supportive sitting (Capelovitch, 2018). For support and for symmetrical activation of the trunk, both hands of the mother need to be placed laterally on the infant's trunk and pelvis during the measurement. Sitting at a table will allow further postural support and equipment that will be used for the VEMMT can be stored under the table to prevent unnecessary distractions.

### **2.3.2 Head movement**

Clinicians have noted that as the performance of eye movements deteriorates the major compensatory act is head movement in support of the defective eye movement (Thorn et al., 1994). As clinicians we cannot instruct the infant not to move the head during certain measurable items. In designing the VEMMT it was decided not to instruct the PCG to hold the infant's head and rather note any movement of the head (Maples, 1995). The reason for this being, that the VEMMT must be as closely as possible to the spontaneous functional vision of an infant during the engagement of a typical social interaction and/or play with a toy. After all caregivers do not instruct infants not to move their heads when they are performing activities during communication or when the infant inspects a toy when holding it in midline with both hands. Theoretically this head movement propensity was thus viewed as potentially valuable information which could be lost if under very short duration testing the infant's head was restricted.

### **2.3.3 Upper extremities**

The infant can free his upper extremity for reaching in unsupported sitting at 6-to-7-months of age (Bly, 2014). The infant is most efficient when reaching for toys in front of the trunk. The infant can grasp the toy and bring the toy to the mouth (Bly & Ariz,

1995). When the trunk is held, the infant can reach and grasp toys from an easy distance that fit into the palm in the sagittal and frontal plane (Polgar, 1995).

Futagi et al. (2017) established that a rudimentary form of goal-directed eye-hand mouth coordination with intention and emotion exists in the new-born human. New-borns can discriminate objects by opening the mouth to an approaching fingertip and a nipple, the two being similar in shape. Infants that are 3-months old and older no longer reacted to the fingertip and open the mouth only to a nipple or food. This type of response not only indicates that infants at these ages, can recognise the difference between shapes but also understand the property of objects. Surprisingly, those young infants have not only the cognitive abilities as to the shape, size, and property of an object but also has visually guided contextual understanding of the situations that they encountered.

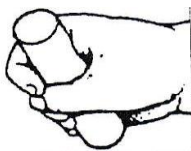
Toys that are larger than the palmar arch are more difficult to the 6-to7-months-old infants to maintain because the digital control is not yet fully developed (Exner, 2010). The specific patterns of grasp observed at this 6-to-7-months of age group are dependent on the size, shape and firmness of the object held (Case-Smith, 1995). Infants are capable of shaping their grip configuration to match the size of objects as early as 4-months old (Barrett et al., 2008).

The transport component, reaching, brings the hand to the target and involves contraction of mainly proximal muscles acting on the shoulder and elbow (Bly, 2014). Grip formation pre-shapes the fingers according to the size and shape of the target object (Jeannerod et al., 1995). Visual information about the intrinsic properties of the target object (size, shape) controls the distal muscles in order to pre-shape the hand (Kuhtz-Buschbeck & Ulmer, 2008). This process implies a visuo-motor transformation that may be accomplished by a neuronal circuit formed by the anterior intraparietal cortex (AIP) and area ventral premotor cortex (PMVr/F5). Area F5 accommodates the grasping neurons that code specific types of prehension such as precision grip or whole hand prehension (Oblak et al., 2021). It has been postulated that AIP provides F5 with not just one, but multiple descriptions of object affordances, because objects are grasped in different ways on the intended action (Kuhtz-Buschbeck & Ulmer, 2008). The appropriate grasp is selected on the basis of prefrontal input which reaches F5 via a pre-supplementary

area and informs about the current goal and the appropriate timing of the action (Rizzolatti & Luppino, 2001).

The infant of 6-to-7-months uses a palmar grasp on a dowel-shaped objects (Alexander et al., 1993). Palmar grasp is a whole hand grasp in which objects are held against the palm of the hand by the fingers, the thumb may be active or passive (Sandler, 2009). However, larger objects that fit easily in the palm are held with a radial-palmar grasp (Alexander et al., 1993). With a radial-palmar grasp the fingers press the object against the radial side of the hand and opposed thumb (Erhardt, 1994). Table 2.1 defines and describes palmar grasp, holding a dowel stick.

Table 2.1: Definition and description of palmar grasp for typical 6-to-7-months-old infants holding a dowel stick

<p><b>Palmar grasp</b></p>	 <p>Adopted from: Alexander et al., 1993.</p>	<p>A grasp in which the index and middle fingers and thumb press an object into the palm.</p>
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The infant at 6-to-7-months can release an object by transferring the object from hand to hand or by releasing the object they were handling onto the table (Alexander et al., 1993). In the clinical setting the analysis of components gives valuable information to determine what is interfering with a reaching task (Marschik et al., 2008). The following descriptions were identified as developmental tasks. Reaching for the object, reaching for and touching the object, reaching for, grasping/handling the object as one-handed (left or right) or two handed and releasing the object are important components (Exner, 2010). A two-handed reach was defined as both hands approaching the object simultaneously, before one hand or both of them contacting the object (Marschik et al., 2008). Reach is visually directed and initiates both hands or can be accomplished with one hand (Greaves et al., 2013). It is noted in the clinical setting that the absence of binocular fixation influences reaching patterns. In an observational study to determine the effect of objects on reaching Marschik et al. (2008), found that infants at 5-months reach often for manageable smaller size objects. They used both hands when an object is larger and only used one hand (favouring neither the left hand nor the right) when reaching for small

objects. Table 2.2 summarized the reaching behaviour as described by Marschik et al. (2008). This study identified the materials and procedures that can be used for the development of the VEMMT.

Table 2.2: Reaching behaviour study in 5-months old infants

<b>Material used</b>	A yellow dumbbell rattle (length 12 cm), a grey cup with a handle with the opening facing up (8 cm x 6 cm x 8 cm), a red block (2.5 cm x 2.5 cm x 2.5 cm) and a red pearl (diameter of 2 cm mounted on a string for reasons of safety).
<b>Procedures</b>	<p>The procedure entailed the infant of 5-months seated on the mother's lap at table level, facing forward, the upper limbs free to move and the trunk supported by the mother. The experimenter was seated on a chair opposite the infant. The objects were placed on the table in random order: at the infant's body midline, at 45 degrees from the midline to the right, and at 45 degrees from the midline to the left. The distance between the hand and the object presented in the midline, was approximately 75% of the infant's arm length. The distance was the same for each object.</p> <p>The dumbbell that was used in Marschik et al. (2008) study was placed horizontally, and the cup was presented with the opening facing up and the handle toward the infant's body midline. Trials were repeated if the infant did not reach for the object instantly, with maximum of three presentations. If the infant did not reach within three presentations, the object was randomly placed in his/her left or right hand; the infant was allowed to handle it for a short time and develop interest. Once the interest was aroused the item was presented to them again. In the case of more than one reach per object presentation only the first one was analysed.</p>
<b>Scoring</b>	Reaching for the object, reaching for and touching the object, reaching for and grasping/handling the object was registered as one-handed (left or right) or two-handed. A two-handed reach was defined as both hands approaching the object simultaneously, before one hand or both of them contacted the object.
<b>Discussions</b>	No infant crossed their midline. Reaching behaviour is space dependent rather than object dependent. If the object is placed at 45° a head turn can be expected.

On the other hand, Kleinow (2007) observed 6-month-old infant's reaching behaviour and used a distance at an extended arm's length. According to the researcher's clinical experience an anterior weight shift is necessary for reaching forward if the object is placed at an arm's distance and therefore the researcher preferred to use 75% of the infant's arm length, as the mother supports the infant at the trunk thereby probably inhibiting any weight shifts. According to the baby size chart ([www.craftyarncouncil.com](http://www.craftyarncouncil.com)) the arm length to underarm for a 6-to-7-months-old infant is 16.5 cm.

A study aimed at investigating whether there are right-left side differences in the reaching kinematics of developing infants, Rönqvist and Domellöf (2006) found that infants at 6-months of age did not show any evident preferences with regard to the frequency of right- or left-sided reaching and grasping. However, they found infants at 12 months have a preference which can be related to the distal progress of hand development. From these results it can be concluded that the frequency of the reaching and grasping behaviour will be equal to both sides for 6-to-7-months-old infants. The objects used in the Rönqvist and Domellöf (2006) study was six differently coloured easy graspable spheres (4 cm in diameter) each with a small bell inside and placed on a base construction. When the infant was judged to be in an alert and optimal state for testing the experimenter attached the object to the displayer. The object to be presented was hidden from the infant until it was positioned.

DeGangi (2000) assessed a visual tactile response by using a 6.5 cm length strip of masking tape with a red dot in the middle, placed on the dorsum of the infant's hand, with the ends free for easy removal. This specific item assessed adaptive motor function and touch tolerance. Any tactile sensitivity will influence the reaching and grasping components. An adaptive response in the form of a voluntary gaze shift to the tape with an attempt to remove the tape, has been observed. By seeing and touching, bringing objects to the mouth and by manipulating them infants can learn about the physical properties of objects for the development of perception, action and memory (Exner, 2010). This illustrates that gaze holding and shifting does not develop in isolation, but it is integrated in purposeful-directed behaviors.

Corbetta and Snapp-Childs (2009), examined different phases of a task that involved seeing, reaching for, touching, grasping and manipulating objects of same sizes and textures contributed to the refinement of subsequent object-oriented motor responses in 6–to-9-months-old infants. Infants were secured in an infant seat with a pillow placed on the top of the infant seat for head support. The examiner sat in front of the infant and presented a small colour ball, 5 cm in diameter; a large ball, 13 cm in diameter varied only in one colour and a large pompon also 13 cm in diameters, with varied colours, by hand and did not place it on a table. It was presented one at a time at midline of the infant. At each trial the infants were allowed time, 30 seconds (s) to hold, explore with the mouth and manipulate before the next object was presented. If the infant did not grasp the object or dropped it before the 30 s elapsed, the experimenter picked the object up and held it in front of the child allowing object exploration to take place. The study concluded that infants of 6-months of age pay more attention to the location of the toys during reaching rather than to the object's specific characteristic. Specific attention to the objects' physical characteristics leading to grip adjustments could become available only once infants have successfully grabbed the toy and manipulated it. A 6-months old infant can release an object through a smooth two-stage transfer or drop an object with a whole arm movement to open the hand for release (Alexander, 1993). Stack and Tsonis (1999) concluded that infants at 6-months of age always looked at the object when reaching and touching but not during manipulating. Findings from the researchers Corbetta and Snapp-Childs (2009) suggested that the successful integration of somatosensory information for tactile discrimination with vision information begins around eight to nine months. The objects were presented by hand to the infant which assisted to stabilize the objects. The researcher experienced this way of presenting an object to an infant at 6-to-7-months-of age is helpful in the clinical setting. The understanding of how you present visual information to an infant can assist or limit the visual processing systems.

The activity of reaching, grasping, holding and release an object involves both the visual system and the sensory-motor cortex. The process involves the recognition of size, orientation and location of the object and then determining the reaching distance, shaping the hand and grasping it for manipulation. To utilized optimal areas of development, systems of intervention are imperative to establish an infant's

potential for optimal functional vision (Groffman, 2006; Russel et al., 2018; Spencer et al., 2012).

The definite characteristics of the human species are the capacity to engage and communicate in a social world (Lloyd-Fox et al., 2014). Eye movements in the context of social interactions will be discussed.

## **2.4 SOCIAL BRAIN**

Eye movements are a key channel of non-verbal communications in humans and eye contact with others is present from birth with eye gaze processing being crucial for social learning (Farroni et al., 2002).

Emotional expression provides a window into an individual's internal experience of the world (Greenspan & Wieder, 1997). Attachment between mothers and infants is the most primitive and primary form of human social relationship (Minagawa-Kawai et al., 2009). Infant-mother attachment is largely based on their experience of mutual interaction and these recognisable reciprocal behaviours are the primary means by which infants prepare for human social activities. Reading and understanding social cues, face recognition, perception and discrimination of affects are important for emotional regulation (DeGangi, 2007).

### **2.4.1 Cortical mapping during social communication**

Social brain areas, specifically the orbital part of the prefrontal cortex, are activated during emotional attachment between mothers and infants (Minagawa-Kawai et al., 2009). The regulation of autonomic responses to social stimuli occurs because the orbitofrontal system is directly connected with the autonomic nervous system and arousal-generating reticular formation (Minagawa-Kawai et al., 2009).

In non-verbal social communication eye gaze plays a fundamental role as human eyes are unique in their morphology. They have a widely exposed white sclera surrounding the darker iris, making it easy to discern the target of another person's attention during face-to-face interaction (Csibra et al., 2008). Sensitivity to eyes and eye gaze is evident very early in ontogeny. Infants exhibit a strong tendency to attend to faces that engage them in mutual gaze when compared with averted gaze (Csibra et al., 2005). The ability to decode social cues from biological motion, such

as eye gaze shifts, eye hand or mouth movements, emotional expression, articulation of the mouth and manual gestures, provides the foundation of social perception and allows us to comprehend and interpret intentions, language, emotions and desire of others (Lloyd-Fox et al., 2011). Biological movements and ostensive signals activating different regions in the social brain during a social interaction and will be discussed in detail in the following paragraphs.

Social interaction and social cognition as seen during face-to-face interaction, direct gaze or hearing a voice calling activate the same neural system. The auditory and visual modalities used for communicative ostensive signals differ in modality and sensory channels, but activate the same social brain regions, namely the dorsomedial prefrontal cortex (mPFC) (Urakawa et al., 2015). Successful communication depends on the recognition of the intention to communicate. Such intention may be conveyed by signals directed at self, such as calling a person's name or making eye contact (Kampe et al., 2018). Humans are extremely sensitive to ostensive signals such as direct eye contact or hearing a voice calling their names (Senju & Csibra, 2008). It is therefore recommended by Urakawa et al. (2015) to use vocal stimuli that accompany visual stimuli to enhance an infant's responsiveness. The perception of facial communication cues involves mutual gaze itself, the eyebrow raises with an accompanying smile in the context of mutual gaze which produce similar social brain cortical activation (Csibra et al., 2008).

Functional cortical specialization involved in face processing is already initiated at the age of 6-months (Minagawa-Kawai et al., 2009). The right hemisphere is active and dominant when an infant at 5-months of age views a face from a frontal view, however the profile view is only active at 8-months of age (Nakato et al., 2009).

Special intonation verbal communication, eliciting eye contact, calling out the infant's name, or positioning oneself in an optimal location for face-to-face communication, are perceived signals to be used for social interaction (Lloyd-Fox et al., 2015). These ostensive signals by the infant activate certain cortical regions. The cortical regions involvement has been identified. It is specialized for the high-level perceptual analysis of faces, places, bodies, visually presented words and even for the very abstract cognitive function of thinking about another person's

thoughts during social interaction, attachments and communication (Kanwisher, 2010).

The mPFC region constitutes an important part of neural circuits for direct gaze during face-to-face communication and gaze following, especially in mutual gaze essential for social interaction (Urakawa et al., 2015). The right dorsolateral prefrontal cortex (R-IPFC) response increases during the reactive time window period (3-10 s) regardless of the partner's gaze of direction. However, the R-IPFC responds to ostensive auditory stimuli presented during the period when the partner's gaze was not direct. An interactive play such as "peek-a-boo" increased responses by both the R-IPFC and mPFC regardless of their gaze direction during the partner's face exposure that is under the ostensive auditory stimuli. In contrast the partner's direct gaze, rather an averted gaze, significantly enhance hemodynamic responses (Urakawa et al., 2015) during face exposure in the mPFC. It can be concluded that the mPFC is generally associated with affective and social processes during mutual gaze perception under ostensive auditory stimuli. The R-IPFC plays a role in face perception and is associated with emotional neutral and cognitive processes (Senju & Csibra, 2008; Lloyd-Fox et al., 2015; Urakawa et al., 2015).

The role of the prefrontal cortex (PFC) in processing multi-modal communicative ostensive signals in infants, measured cerebral hemodynamic responses by using near-infrared spectroscopy (NSIR) during live mutual gaze interactive play was investigated by Urakawa et al. (2015). The 7-months-old infants sat on their mother's lap and looked at a partner's face during a "peek-a-boo" play. Urakawa et al., (2015) also investigated the role of the PFC in infants during an interactive social play, "peek-a-boo" in which both auditory (infant-directed speech) and visual (direct gaze) stimuli were presented. During these multimodal communicative ostensive signals, a presenter hid her face with both hands and called "I am not here" for 3 s, after that she exposed her face, the facing period, with a direct gaze with the call "Baa- baa" for 5 s. After this game she hid her face and the next trial started. The target distance for this interactive social game was 70 cm. The infant's fixation patterns were monitored. The results indicated that an infant fixated on the adult's eyes region for longer duration during social play. Direct gaze during this play shifted an infant's attention to the adult's eyes for interactive communication. It was

concluded that mutual gaze (eye contact) provides the main mechanism of establishing a communicative context in social interaction. Senju and Csibra (2008) reported that infants were more responsive to real-life social interactions situation than watching a face on a video.

Biological motion perception such as eye-hand-mouth-body-movement and gestures are important social cues that contribute to the perception and interpretation of social cues that selectively engages several distinct regions in the brain of the observer (Pelphrey et al., 2005). Biological movements assist with the recognition of a human face. Infants at 6-months of age also start to understand the meaning of each biological movement. As this natural exploration process proceeds infants build up their image libraries, cross-referenced through the other senses. Schiltz et al. (2010) have shown evidence in their scanning study that the right temporal lobe provides the main image library to all the faces one has remembered and recognises while the left temporal lobe provides the main library of the shapes and objects one expects to recognise in everyday life. Pictures of faces display increased activity in the right temporal lobe in infants with extra activity in the left temporal lobe when their mother's faces are shown (Nakato et al., 2011). This rudimentary perception of biological motion is, from an intrinsic capability of visual mechanisms to direct our attention to biological motion (Christie & Slaughter, 2010). Already by the age of 4-months, infants differentially engage temporal, as well as frontal (premotor) cortical regions when processing an agent's action. This process is similar to that in adults despite having little or no experience with the observed actions (Grossmann et al., 2013) indicating that the brain responses are sensitive to the form and motion characteristic of an adult (Pelphrey et al., 2005).

The brain regions in the social brain have been identified during social interactions. Although different methods are designed and used to detect different correlates of brain activation during social interaction and communication, the researcher investigated studies of Lloyd-Fox et al., (2009, 2011, 2014) that are based on near-infrared spectroscopy (NIRS) and/or functional near-infrared spectroscopy (fNIRS). These methods are used to reveal the brain activity that underlies cognitive, object and face processing in human infants with both being suitable for infants in a naturalistic setting. In the studies investigated during NIRS/fNIRS, infants between 5-to-7-months of age were exposed to ostensive signals or with biological

movements. What makes these methods so special and important for the current study is during the social active play, eye tracking behaviours on the infants were simultaneously recorded along with measurement of hemodynamic responses (Lloyd-Fox et al., 2014). The fNIRS techniques have been used to address developmental topics such as object processing, social communication, human action processing, face processing for the measurement of hemodynamic responses while infants watched a visual-social activation or vocally selective activation (Urakawa et al., 2015). Specific looking behaviours were recorded along with the hemodynamic activity in a brain region. Infants spent more time looking to the eye region of the agent's face when the agent looked directly to the infant with or without auditory stimuli and during social interactive play (Franchak et al., 2017).

Many fNIRS studies (Braukmann et al., 2017; Grossmann et al., 2013; Lloyd-Fox et al., 2015) highlight cortical activation to various visual social cues during infancy. During interaction with the infant, fNIRS studies revealed the temporal-parietal brain region of the infant to be active for perception of whole-body movements of the agent (Reid et al., 2006). Eye contact and gaze direction activate the temporo-parietal regions (Grossmann et al., 2013). The temporal regions demonstrate stronger activation when infants listen to vocalizations that include speech, laughter, coughing and crying compared with non-vocal environmental sounds (Lloyd-Fox et al., 2015). The tracking behaviours recorded the duration of fixations to a region, the direction of gaze, direct gaze, visual fixation patterns, the visual following behaviour of the agent's gaze (a potential communicative-referential signal), eye contact and viewing behaviour during a live interaction or using televised screens (Shimada & Hiraki, 2006; Lloyd-Fox et al., 2015; Christie & Slaughter, 2010; Csibra et al., 2008; Lloyd-Fox et al., 2014).

Research has revealed that children under 3-years of age who are given information on video often do not perform as well on measures of learning as do those who get the same information directly (Strouse & Troseth, 2008). Direct interaction not only encouraged direct gaze for communication but also, they look to him/her for information about the shared environment (Strouse & Troseth, 2008). Sharing focus on elements of the infant's environment being viewed will be a key factor during the baseline measurements especially when the infant attempts to communicate. Therefore, live situations will be applied in the current study.

Warreyn et al. (2013) recommended the use of live actions to investigate mirroring in young infants as live stimuli provide a more realistic view on brain processing because these stimuli are efficiently processed due to the similarity with the real world. It can be concluded that as the emphasis is on functional eye movements in the current research, it is important to test the infant in a naturalistic situation with good social communication and direct eye contact for attention.

Lloyd-Fox et al. (2014), have successfully piloted a fNIRS as a neuroimaging tool in rural Gambia to assess cognitive functions in rural Africa in 4-8-months old infants, watching videos of Gambian adults perform social movements, as hemodynamic responses were recorded using fNIRS. The patterns of the posterior superior temporal and inferior frontal cortex that evidenced either visual-social activation or vocally selective activation in Gambian infants replicated those observed within similar aged infants in the United Kingdom (UK). Interestingly, the specificity of the responses of the Gambian infants to the visual social vs non-social stimuli was the same as the infants in the UK, despite substantial differences in their socioeconomic, cultural and geographic environment.

Autism can be identified from around the end of the first year on the basis of atypical social and non-social behaviours such as unusual eye contact, lack of orientation to name and reduced flexibility in switching attention. The following researchers, (Elsabbagh & Johnson, 2010; Lloyd-Fox et al., 2013; Rogers, 2009; Wan et al., 2012) used the same protocol from their previous work to determine if reduced neural sensitivity to social stimuli in infants at risk for autism differs from typical infants. Atypical responses to social stimuli were documented indicating atypical functioning in the social brain network. Critical early signs of atypical social development in autism are impairment of face perception and eye gaze (Urakawa et al., 2015). Thus, it can be concluded that atypical eye movements in 6-month-old-infants can be an indication of neurological insults. The aim of early intervention for high-risk infants is, amongst others, to establish an infant's potential for optimal visual functioning in all developmental areas. The value of the finding of the above studies is summarized in Table 2.3 and will serve as guidelines for the development of the VEMMT.

Table 2.3: Summary of the social brain towards the development of the VEMMT

<b>Area of importance</b>	<b>For consideration in the development if the VEMMT</b>
<b>Ostensive signals</b>	Use combination of ostensive signals namely infant directed speech gestures and direct gaze. This will lead to enhanced brain activation for responsiveness in infants.
<b>Plane of viewing</b>	Use frontal view but not the profile view that is only active at 8-months of age.
<b>Mutual gaze</b>	Mutual gaze itself, and the eyebrow raise with accompanying smile in the context of mutual gaze, produce similar social brain cortical activation that involves the perception of facial communication cues. Voluntary eye movements are important in communication and social interaction for attachments and bonding.
<b>Environment</b>	Naturalistic communicative interaction environment is important. Real life situations increase hemodynamic responses.
<b>Gestural acts</b>	The 6-months-old-infant takes into account all available information for figuring out whether they are being addressed by a communicative source and invests more effort into the processing of vocal and gestural communicative acts.
<b>Cortical regions</b>	Already by the age of 4-months old infants differentially engage temporal as well as frontal (premotor) cortical regions when processing an agent's action in an adult-like manner and at an age which infants have little or no experience with the observed actions indicating that the brain responses are sensitive to the form and motion characteristic of an agent.
<b>Perception of social cues</b>	It is evident that perception of differing social movements, signals or cues can cause neural activation in different locations of the cortex implying the social brain regions are activated to social dynamic stimuli from very early on in life.
The procedures, equipment used, administration and results of the studies reviewed do provide valuable information for the development of the VEMMT in 6-to-7-months-old infants.	
Directing, shifting gaze, focussing, following social cues or actions in a social context during live interactive social play activates many brain regions.	

Voluntary eye movements, with its neuronal structures of perception and action, make purposeful interactions possible between the individual and the environment (Buultjens et al., 2010) and are illustrated in Figure 2.1. Figure 2.1 capturing the essence of VEMs and how it relates to other dynamic systems for the identification of domains, sub-domains and items. Figure 2.1 will be used to orient the reader along while each section under investigation will be highlighted in yellow.

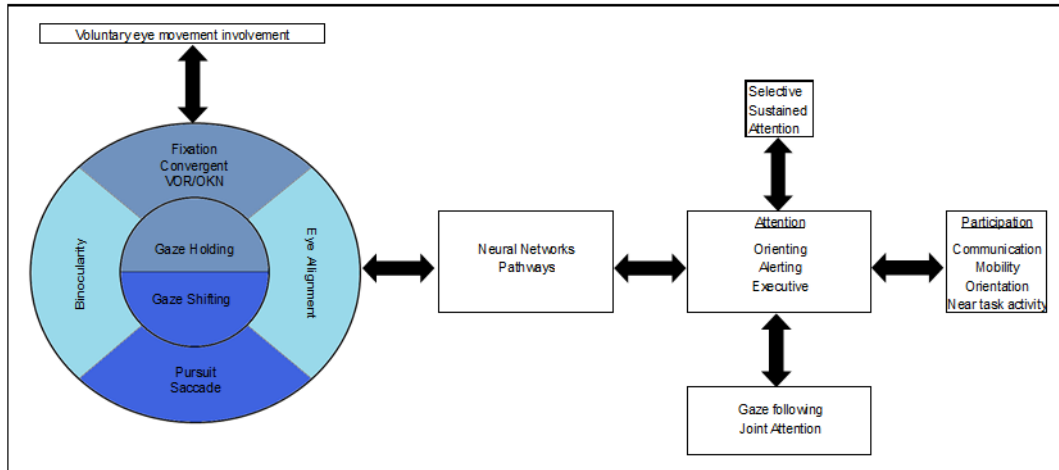


Figure 2.1: Voluntary eye movement and how it relates to the dynamic systems

The understanding of the neural control for VEMs with its interconnectivity for purposeful goal-directed actions will assist to identify the items for the development of the VEMMT.

## 2.5 NEURAL CONTROL OF VOLUNTARY EYE MOVEMENTS

The understanding of the neuronal networking of VEMs mechanisms that underlies typical functional vision development is important to create early intervention strategies to optimize or enhance the neural connectivity for myriad developmental phases. Figure 2.2 summarizes the interaction of the neural control and VEMs.

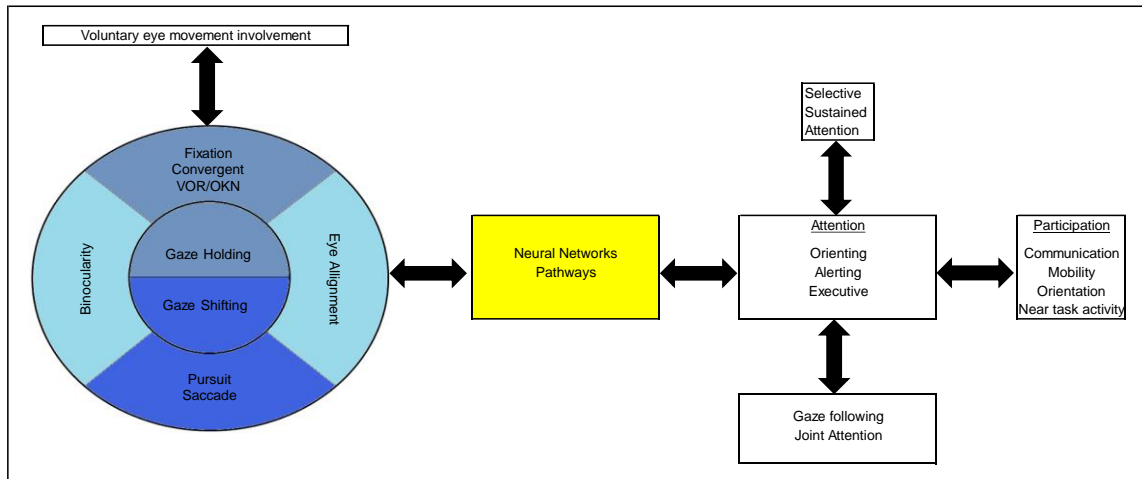


Figure 2.2: Neuronal network pathways and connections

We are confronted with an overwhelming amount of information each time we open our eyes. We experience a seemingly effortless understanding of our visual world. While we move either by translation or rotation through space, the neural control of eye movements brings about resolution of the visual field (Trotter et al., 2012). Body motion causes the image of the visual field to flow across the retina and reflexive eye movements reduce or stabilize the image motion to improve visual performance activities. The combination of body and eye movements is however, outside the scope of the current research study and thus not deliberated on in any detail.

The neuronal networking for the recognition and spatial processing of objects, people and events addresses the questions: “what is it?” and “where is it?” (Atkinson, 2002), whereas the emotion-attentional-regulatory neuronal processing networks through the visual system address the questions: “is it good for me?” or, “is it bad for me?” and “what shall I do about it?” (Posner et al., 2014).

Gaze holding and shifting improve visual resolution of individual objects by maintaining alignment of the two foveas with both stationary and moving targets over a broad range of directions and distances of gaze (Pitkow et al., 2007). The three pairs of extraocular muscles in each eye provide control of horizontal, vertical and torsional position in that eye and is discussed in another section. The emergence of organized patterns of activities reflects the normal structure and function of the CNS.

### **2.5.1 The perspectives of the developmental neuroscience**

Developmental changes are the result of underlying structural and functional brain maturation (Senju et al., 2006). Tools like the electroencephalogram (EEG), event-related potentials (ERPs), the magnetoencephalogram (MEG), functional near-infrared spectroscopy (f-NIRS), structural and magnetic resonance imaging (MRI) and functional magnetic resonance imaging (f-MRI), assist clinicians and researchers to understand how the brain develops, before and after birth. It also assists in knowing how the brain interacts with the environment during both pre- and postnatal development to produce sensory-motor-perceptual activities. Both prenatal, a set of internal events occurring early after conception and up to birth, and early postnatal experiences, that refer to the external sensorial events arising from early exposure to the extrauterine environment (Mento & Bisiacchi, 2012), are fundamental for the development of the CNS and the emergence of an organized pattern of activities that reflect normal structures and functions. However, these early sensory experiences that a full-term new-born usually encounter is due to typical intrauterine development mediated by maternal biological protection from environmental perturbations. The supply of nutrients, control of temperature and chronobiological rhythms leading to a level of neurobiological maturation sufficient to enjoy the organized sensorial experiences are provided by the early extrauterine environment (DeRegnier et al., 2002). This detailed intrauterine development is also outside the scope of this study and will not be discussed further.

To optimize performance and develop the phases of transition the neural control of eye movements is organised (Hadders-Algra, 2018) which are affected by the features of the child and the environment (Colenbrander, 2003). Vision rapidly improves with different visual capabilities emerging at different stages as infants experience the normal visual environment (Kiorpes, 2015). Eye movements and the neuronal-networking involvement allow functional visual information to be processed efficiently for perception and cognition, memory, organized purposeful actions and attention (Hyvarinen, 2010).

### **2.5.2 Cerebral plasticity**

Coordinated, experience-driven changes in synaptic efficacy are required for the proper development of brain networks (McCoy et al., 2009). This plasticity has been

well-studied in the visual cortex. A brief period of monocular deprivation produces amblyopia as a consequence of reduced synaptic inputs to the cortex (Kim et al., 2009). Monocular eye closure during the first few months of life causes a sharp decline in the number of synaptic inputs in the lateral geniculate bodies and visual cortex (Willoughby et al., 2015; Ismail et al., 2017; Meredith et al., 2012). Hubel and Wiesel (1963) mentioned that there are sensitivity and critical periods for neuroplasticity that enable the construction and consolidation of experience-dependent structural and functional brain connections. They showed that visual deprivation during a specific window period of young brain development leads to alteration in the visual cortex network. They thus deemed that visual experience during that period is critical for normal neural circuit development and that restoration of normal visual experience after that period does not remediate the abnormal circuits.

Binocular imbalance commonly results from monocular form deprivation, monocular defocus, and/or misalignment of the visual axis causing abnormal reorganization in the visual brain (Chidambaram & Lietman, 2005). Amblyopia is likely to develop in the affected eye if the visual condition responsible for binocular imbalance remains untreated (Asper et al., 2000). Moreover, eye movements are established and fine-tuned in early life by visual experience with the first 3-months of life being critical for the development of binocularity (Atkinson, 2002).

### **2.5.3 Developmental plasticity**

In the brain connectivity is the king, empowering the wiring for synaptic plasticity, (Anderson, 2010) and this configuration of connectivity determines function for participation. Neuroplasticity can generally be defined as any change in the configuration of connectivity on a structural and functional level (Kleim et al., 1998). Neuroplasticity refers to the inherently dynamic biological capacity of the CNS to undergo maturation, change structurally and functionally to experience and to adapt following injury (Ismail et al., 2017). Ineffective synaptic connection will be weakened and effective synaptic connections between individual nerve cells will be strengthened, and neurons that fire together will wire together (Anderson, 2010). In the developing brain, several mechanisms contribute to the intricate balance, not

too rigid and not too flexible, for functional synapses to develop and for network stability.

A crucial aspect of human development is the ability to shift attention from one visual stimulus to another. It allows infants to learn of relevant events and direct processing. Shifts in the direction of attention are closely linked to shifts in the direction of gaze and gaze holding (Fischer & Breitmeyer, 1987; Stelmach et al., 1997; Zhao et al., 2012; Scholz et al., 2018). The alignment of attention with a source of sensory input does not always have to be directly observable (Hunnius & Geuze, 2004). Moreover, gaze shifts are not necessary to shift attention to a target and fixating on a target does not guarantee it will be attended to (Zhao et al., 2012). Nonetheless you cannot shift gaze and hold your gaze without attention. In clinical practice, it has been observed that infants with neurological insults, very preterm birth infants and infants with genetic and/or developmental disorders have deficits in the ability to direct and maintain attention. They cannot shift their gaze to a target of interest or have difficulty in keeping their fixation on a target influenced goal-directed action. How various components of visual attention with their distinct and likely independent developmental courses interact to produce the types of eye movement behaviour prompted investigation for the development of the VEMMT.

## **2.6 ATTENTION**

This study did not intend to measure visual attention in infants but rather to identify VEMs in the attentional paradigm. The inter-relationship between eye movements and attention is demonstrated in the following Figure 2.3. Gaze following and joint attention will be discussed under gaze shifting. Attention has emerged as an important topic for the development of the VEMMT.

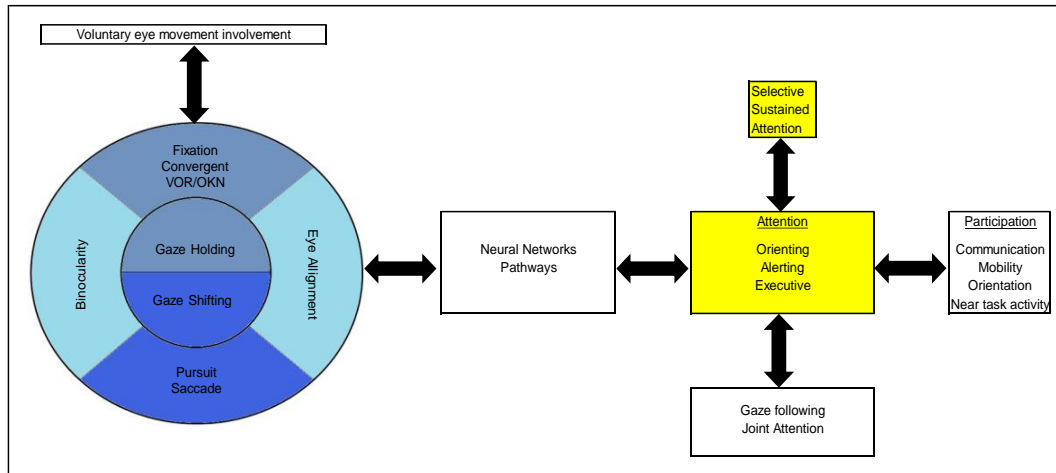


Figure 2.3: Inter-relationship between VEMs and attention

The human brain processes the activity of hundreds of millions of sensory receptors to create a representation of the sensory world that involves billions of neurons in the cerebral cortex (Kolb et al., 2017). At any given time, however, we can act on only a tiny fraction of the available signals. Attention is the process of selecting a manageable subset of signals that is appropriate to guide action in the current behavioural context. Attention may also be referred to as a state of preparedness or readiness known as alertness (Atkinson & Braddick, 2012; Hoang Duc et al., 2008; Van der Stigchel & Nijboer, 2017; Felleman & Essen, 1991).

For infants, gaining control over attention in their daily life are crucial for exploration and to learn about the surrounding world that forms the basis for cognitive, social (Hunnus, 2007) and motor development (Hadders-Algra, 2010; Garbutt et al., 2006).

### 2.6.1 Relationship between eye movements, attention and self-regulation

Landry et al. (1985) investigated the differential effects of intraventricular haemorrhage and respiratory distress syndrome that are closely associated with prematurity, on early visual attention and information processing skills (Atkinson & Braddick, 2012; Stockall et al., 2021). The amount of time needed to orient to a visual stimulus, and the duration of fixation once being oriented, were compared. They concluded that attention-getting and shifting were delayed with preterm infants with intraventricular haemorrhage (IVH) and respiratory distress syndrome (RDS)

which may be associated with having difficulty in inhibiting a response to a blinking light to attend to another visual stimulus.

At 4-months of age, infants have gained control in orienting and can disengage attention from one location and move it to another. Self-regulation lies in the infant's capacity to take interest in the world while simultaneously regulating arousal and responses to sensory stimulation (DeGangi, 2000). The capacity for engagement and attachment has to do with the ability to modulate, process sensory experiences and to coordinate motor actions (Greenspan, 2010). Observations and measurement should be carried out when the 6-month-old infant is in a quiet alert state four (Costa et al., 2010). According to Costa et al. (2010) a state four is defined as quiet alert with a bright look and focus is on visual or auditory stimuli with minimum movements.

The process of self-regulation involves the capacity to modulate mood, self-calm delay gratification and tolerated transitions of activities (DeGangi, 2000). Most infants can self-calm by bringing their hands together looking or listening to stimuli. They can quiet by the distraction of a novel object/toy for as long as 1 minute, indicating that the visual orienting network plays an important role in emotional control and self-regulation (Rothbart et al., 2011). These behaviors are often unavailable to infants with regulatory disorders, and once upset extreme efforts are required to calm down. Fussiness, irritability, intense crying or escalating quickly from a pleasant mood to an intense cry can be observed (Greenspan, 2010).

Early rudimentary systems of executive attention are a predictive behaviour of later self-regulation (Sheese et al., 2008). Caregivers use somatosensory systems such as rocking or massage to reduce infants' distress. Infants regulate distress through physical self-soothing activities such as hand to mouth. Infants who developed executive attention capacities show a greater tendency to inspect the toy visually before reaching, grasping and manipulating. This means, according to Sheese et al. (2008) that infants at 6-months exhibited a form of effortful control over their movements and suggested that early regulatory systems include control over the speed of initiating movement.

### **2.6.2 Sustained attention**

Sustained attention is the ability to direct and focus cognitive activity on specific stimuli (DeGangi, 2000). A necessary requirement for information processing is sustained attention. Without this ability an infant will have enormous interference in developing cognition. Sustained attention is the ability to have first eye-gaze with a responsive, interactive parent. The prolonged fixation time is a form of executive function (Del Bianco et al., 2018), correlated with the duration of visual orienting, and predicts self-regulatory behaviour (Vaughan Van Hecke et al., 2012). Infants with regulatory disorders show problems sustaining their attention during novel visual, auditory, tactile, or multisensory activities (DeGangi, 2000). The researcher adopted the theory of DeGangi (2000) that categorized sustained attention into three categories, namely, attention getting, holding and releasing. Visual attention-getting and holding, can be measured in conjunction with voluntary gaze shifting and holding eye movements (Xie & Richards, 2017).

### **2.6.3 Attention getting**

The initial orientation or alerting to a stimulus is considered attention-getting. It can be observed in head-turning or a gaze shift toward a large, bright object presented in the periphery and/or in the central visual field (Landry et al., 1985; Curtindale, 2014). Faces, bold patterns, motion, large objects, or loud sounds are the characteristics of stimuli to get an infants' attention (DeGangi, 2007). Similar to the orienting alerting networks which is essential for survival and important mechanism for attention to novelty are the attention-getting process. Orienting visual attentional behaviour is under the control of a distributive network of brain areas involved in sensory, motor and executive functions (Atkinson & Braddick, 2012). Figure 2.4 is an overview of the visual neuronal orienting network and the description of the functional roles.

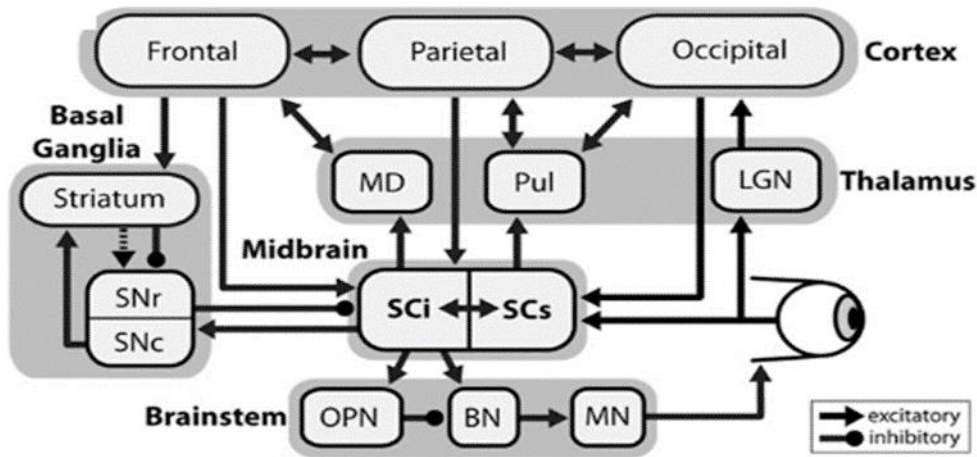


Figure 2.4: Visual orienting network (**Adopted from: White BJ, Munoz DP 2002**)

Orienting within the visual field is one of the earliest functions to emerge in infancy (Corbetta & Snapp-Childs, 2009). In our daily life, we are exposed to many different clutter environments and objects that compete for the control and processing of attention and eye movements (Hoang Duc et al., 2008). Objects can get selected in a voluntary goal-directed manner, with intention. But, when specific properties in the visual environment determine what is selected, regardless of the observer's goal or intention, the selection is said to occur in a stimulus-driven manner that transforms complex visual input into a spatial map of visual prominence (Kooiker et al., 2014).

Salient objects that appear suddenly in the visual field for example, often capture attention even if they are irrelevant. A defensive blink response indicates a response to a stimulus-driven response (Sambo et al., 2012). Atkinson (2002) used a plexiglass screen held 5 cm from infant's face and tapped with the fingers. Then the hand of the examiner was withdrawn from the screen and moved smoothly with palm forward towards the screen. A pass is scored if there is a blinking either in 1/1 trials or 2/3 trials.

An understanding of the neural mechanisms in visual orienting network/attention getting, as well as the areas that could be affected in new-borns when assessing eye movements is important.

#### 2.6.4 Superior colliculus

Most brain areas in the visual orienting network converge in the midbrain including the superior colliculus. The superior colliculus (SC) is multi-layered but can be

divided into two dominant functional layers: a superficial visual-only layer (SCs) and an intermediate/deeper multisensory, cognitive and motor related layer (SCi). The SCs receives visual information via direct projections from the retina and via indirect projections from the retino-geniculate-cortical pathway. The SCi is the major point of convergence of descending saccade-related signals from fronto-parietal cortices and the basal ganglia as well as converging visual inputs from the SCs and extrastriate visual cortical areas. It is the SCi that is associated with motor preparation for saccades, covert attention and reward (Zhao et al., 2012).

The SC visual and motor maps thus are spatially aligned and project to the brain stem to trigger saccades and/or head movement. Subsequently, the SC underpins this initial attentional ability of new-borns including eye and head movements (Atkinson & Braddick, 2012). Failure to demonstrate this basic orienting response, seen in the clinical practice may imply insufficient development in this area (Ross-Sheehy et al., 2015).

#### **2.6.5 Occipital lobe**

The occipital cortex is the central visual processing hub of the brain and is the major source of visual input to the orienting system. Visual signals from the retina traverse parallel pathways devoted to specific chromatic and spatio-temporal aspects of the visual input, the so called magno- and parvocellular paths. These pathways terminate in the primary visual cortex also referred to as area V1. A hallmark of neurons in V1, in general, is their selectivity for visual features such as colour, orientation or direction of motion (Kandel, 1991).

In addition, visual signals split into two broadly construed processing streams:

- the ventral stream associated with the processing and perception of objects and
- the dorsal stream primarily concerned with the control of actions, including eye movements (Dutton, 2013).

Saccadic selection of stimuli in complex visual environments would not be possible without the ability to distinguish features that define behaviourally relevant stimuli. Because cortical areas involved in eye movement such as SC and the frontal eye field (FEF) are not selective for visual features, saccade target selection must

involve important communication between these areas and the visual cortex. Interestingly, the SC and FEF receive direct inputs from visual cortical areas belonging to both the dorsal and ventral streams (Boyd & Matsubara, 2011).

### **2.6.6 Fronto-parietal cortices**

Several nuclei in the frontal and parietal cortices play an important role in the control of visual attention and voluntary gaze shifting/behaviour. Similar to the SCi the FEF projects to the brainstem saccadic circuitry and contributes to the transformation of visual signals into saccadic commands. The FEF also projects directly to the SCi and is important for voluntary saccade control. The supplementary eye fields (SEF) also project directly to the brainstem and SCi and play an important role in the executive control of saccades. The posterior parietal cortex, known as the lateral intraparietal area (LIP) plays an important role in higher-order visual processes associated with orienting and attention. Although LIP has a direct projection to both FEF and SCi it has been argued that LIP does not participate directly in the production of saccades (Boyd & Matsubara, 2011).

### **2.6.7 Basal ganglia**

The basal ganglia represent an important group of subcortical nuclei involved in voluntary motor control, learning and reward. With respect to visual orienting, the basal ganglia mediate pathways between the cortex and the SCi influencing the SCi through direct inhibitory projection from the substantia nigra pars reticulata (SNr) to regulate saccadic burst initiation and thereby drive the appropriate orienting response (Wu et al., 2022).

### **2.6.8 Brainstem**

The brainstem reticular formation contains a group of nuclei that form the central generator mechanism. The paramedian pontine reticular formation (PPRF) and medial longitudinal fasciculus (MLF) determine the horizontal and vertical components of the saccade. Tonic discharge from the omnipause neurons acts as a gate that inhibits saccade burst neurons in the PPRF and MLF to control when a saccade may be initiated. A saccade is initiated by a trigger signal from the SC which disinhibits the omnipause neurons for a brief moment, allowing burst neurons to

generate the pulse of activation required to produce a saccade of a specific amplitude and speed determined by the neural integrator (Krauzlis, 2014).

### **2.6.9 Attention holding**

Maintenance of a stimulus either intricate or novel is attention holding. It is reflected by how long the infant engages in cognitive activity involving a stimulus (DeGangi, 2000). An infant will engage in attention holding by inspecting the object visually and manipulate it using their fingers pending on the texture of the object. It has been observed in clinical practice that infants from 6-to-7-months-of age tend to rake their fingers on textured objects and squeeze on soft toys. The most potent mediators of attention holding are novelty and complexity. It involves interesting patterns, bright colours, unique spatial orientations, surprised looking faces and meaningful events such as feeding time. If an object, activity or event is not complex and the demand to press information is low the duration of attention holding will be short (Courage & Richards, 2008).

### **2.6.10 Attention releasing**

An infant will turn away from the stimulus in a consistent manner for e.g., look down when finishing with the attention holding. Attention releasing assists the infant to shift attention to something new. Attention releasing will be discussed later in more detail during the saccadic eye movements as disengagement is a pre-requisite to make VEMs (DeGangi, 2007).

The inter-relationship between attention, gaze holding and shifting with its neuronal networks have been discussed previously. Shifts in the direction of attention are closely linked to shifts in the direction of gaze and gaze holding (Lunghi et al., 2020).

The researcher explored different approaches, assumptions, frameworks, expectations, and theories; particularly on how VEMs are related to the functional visual system for the development of a VEMMT in infants 6-to-7-months of age (cf. 1.2.2).

## **2.7 THEORIES AND THEIR RELATION TO TYPICAL DEVELOPMENT AND EYE MOVEMENTS THAT ARE RELATED TO FUNCTIONAL VISION**

Typical motor development has too often been considered as achievement of a set of milestones. Scientists in the last decade have succeeded in a better and more detailed description of observable changes occurring during early sensory-motor development (Hadders-Algra, 2018). Voluntary eye movements are not a set of milestones to measure. Therefore, measuring eye movements per se will not indicate how the neuronal networks interact for a purposeful participation in an ever-changing environment as attention interfaces at all levels. Eye movements per se therefore do not occur in isolation but are interconnected with other multiple systems. The ICF-CY has been used as the main reference for the development of the VEMMT (Simeonsson, 2009).

The ICF and the ICF- CY is a framework that organizes, labels, and categorizes biological and social perspectives of health and disability. The ICF framework is a classification system and not a measurement system (Simeonsson, 2009). Figure 2.5 depicting the integration and relationship with functional vision and the ICF-CY. As a clinician, the researcher viewed each domain carefully and very specifically its domains, sub-domains, and measurable items for the development of the VEMMT.

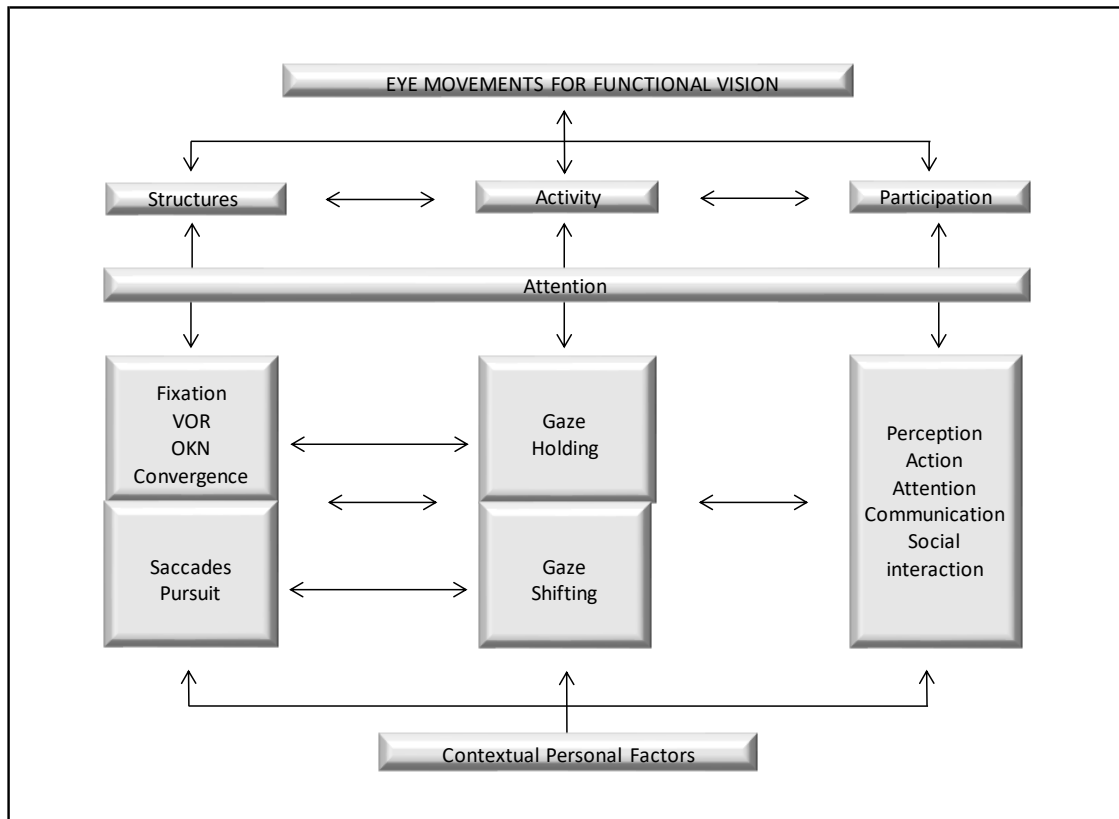


Figure 2.5: VEMMT from a functional perspective incorporated in the ICF model

The ICF-CY model fits well within the scope of practice of OT. The function of each system is usually related to the functions of multiple other single systems. The ICF-CY has been used as a reference for the development of the VEMMT. The broad definition for VEMs for this research was compiled as:

Voluntary eye movements for 6-to-7-months-old infants are the foundation to process functional visual information efficiently for perception and cognition, memory, organized purposeful actions, and attention on an ever-changing environment in all cultures to promote communication/social interaction, activities of daily living, near task work, and mobility/orientation (Hyvärinen, 2019; Scheiman, 2011).

The desired outcome of the VEMMT is not only to measure VEMs per se (main domains) but also to observe each infant in different functional visual activities in meaningful life settings (sub-domains).

## **2.8 VOLUNTARY EYE MOVEMENTS**

### **2.8.1 Conceptualization of the voluntary eye movement measurement tool**

The development of eye-tracking systems has provided a tool capable of evaluating eye movements (Majaranta & Bulling, 2014), however they remain expensive, do not measure the functional outcome of eye movements in early life, and are currently not a practical option for the clinical assessment of functional VEMs in infants 6-to-7-months of age. Moreover, currently there exists no common format to assess functional VEMs in infants 6-to-7-months of age which limits the interpretation of the visual behaviour in this age group (Maino, 2012). The unavailability of a clinical measurable tool to detect eye movements anomalies in the young infant is thus a huge shortcoming. As the manifestation of atypical eye movements is relatively high following brain damage due to visual processing disorders (Guzzetta et al., 2007), early detection of eye movement anomalies is important. Furthermore, given the importance of the role of eye movements interaction with their visual environment, this field is of particular interest to OTs working in the field of neurodevelopmental therapy (Stolk et al., 2009).

The occurrence of eye movement deficits can serve as a marker of damage to the anterior part of the eye (Colombo & Mitchell, 2009). Moreover, it presented the postulation that eye movements can be markers of cerebral or cognitive visual impairment due to focal brain injuries such as arterial or venous stroke, focal intracranial haemorrhage, traumatic brain injury, infections of the central nervous system, neonatal hypoglycaemia, epilepsy, metabolic disorders or brain malformations such as hydrocephalus (Pratesi et al., 2015).

### **2.8.2 Clinical importance of measurement tools for voluntary eye movements**

Most existing tests of vision-related functioning are designed for adults (Leat et al., 2009). The difference between adults and infants is as follows.

Infants cannot:

- be asked to make rapidly a single eye movement directed towards the sudden onset of an eccentrically placed target.
- be instructed to make a single eye shift or track to whichever peripheral target catches their attention.
- choose the target based on the perceived difference in onset.

For infants at risk, the situation is different as no voluntary eye movement measurement tools exist for 6-to-7-months of age that is related to functional vision. Loss of vision in the adult is fundamentally different from the lack of visual processing from an early age (Maino, 2012). The development of visual assessments for infants are not easy.

### **2.8.3 Preferential looking paradigm**

Shifting and holding gaze can be measured during the presentation of a preferential looking paradigm. Preferential looking is based on the infant's preference for colour, objects, contrast, contours, faces, direction and speed of the movement of targets and against a patterned/plain; a moveable /non-moveable background (Kooiker et al., 2014). The main advantage of using the preferential looking paradigm in the clinical practice, reaction to gaze holding, and shifting are that they can be calculated and that it does not require infants to verbalise their symptoms as they also do not follow instructions (Hyvärinen, 2013). In the following section, the two main domains, gaze holding and gaze shifting will be defined and unpacked for the identification of items to be used in the VEMMT.

### **2.8.4 Domains of functional voluntary eye movements**

Voluntary eye movements are responsible for localizing targets onto the fovea, the most sensitive part of the retina. For the clearest image, infants move their eyes to ensure the image of regard falls onto the fovea (Blake & Wilson, 2011). Hyvärinen (2013) reported that if an infant does not gain motor fusion or eye teaming this deficiency can become a great deterrent to all judgments of spatial orientation, depth perception and to have an accuracy of a clear single image. Gaze holding and shifting are the essence of voluntary eye movements and is illustrated in Figure 2.6.

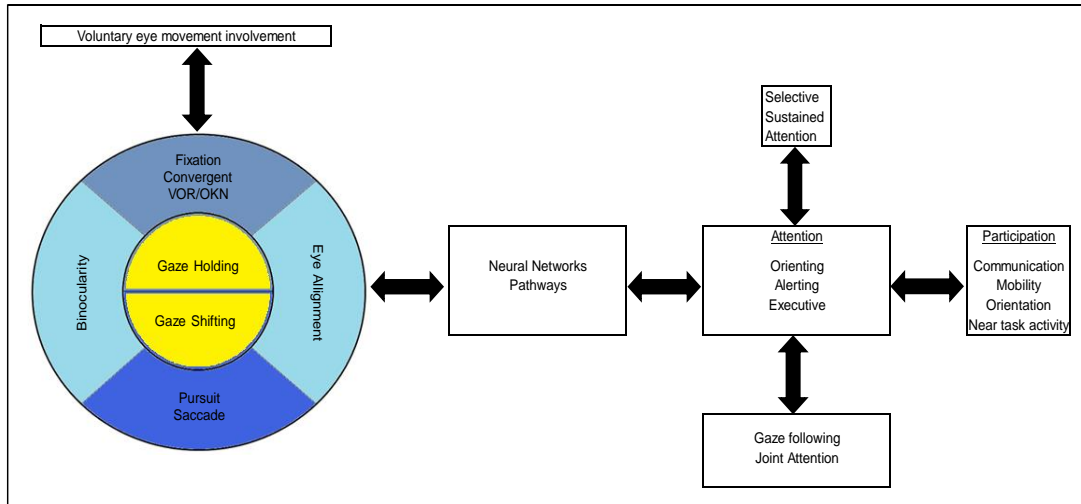


Figure 2.6: The two domains, gaze holding and shifting

## 2.9 GAZE HOLDING

The main function of the vestibular-ocular-response (VOR), optokinetic-nystagmus (OKN), and visual fixation is to hold an image of the seen world steady on the retina. Thus, they are classified as gaze holding eye movements. The VOR and OKN are involuntary eye movements that occur continuously in response to head movements and self-propelled movements or movements of the visual environment (Furman, 2014). In the clinical practice, VOR and OKN are important treatment strategies, especially, if VEMs are absent due to damage to the visual brain networking. In this research OKN is not under investigation. The VOR is under investigation in a frontal plane movement and will be discussed under gaze pursuit (cf. 2.14).

Gaze holding means holding the image on the fovea. Erhardt (1987) described gaze holding as “grasping with the eyes” by first directing the eyes to a target and then hold the eyes so that the target lies on the visual axis producing impulses that are carried along the visual pathways. Figure 2.7 summarizes the main domain gaze holding and the sub-domains. Figure 2.8 summarizes the path taken to identify the sub-domains and items.

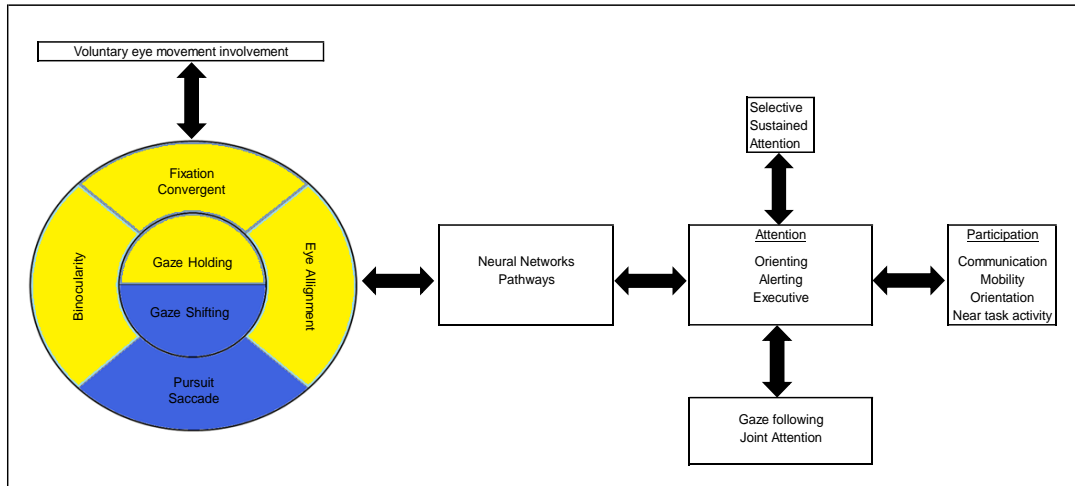


Figure 2.7: Gaze holding and sub-domains

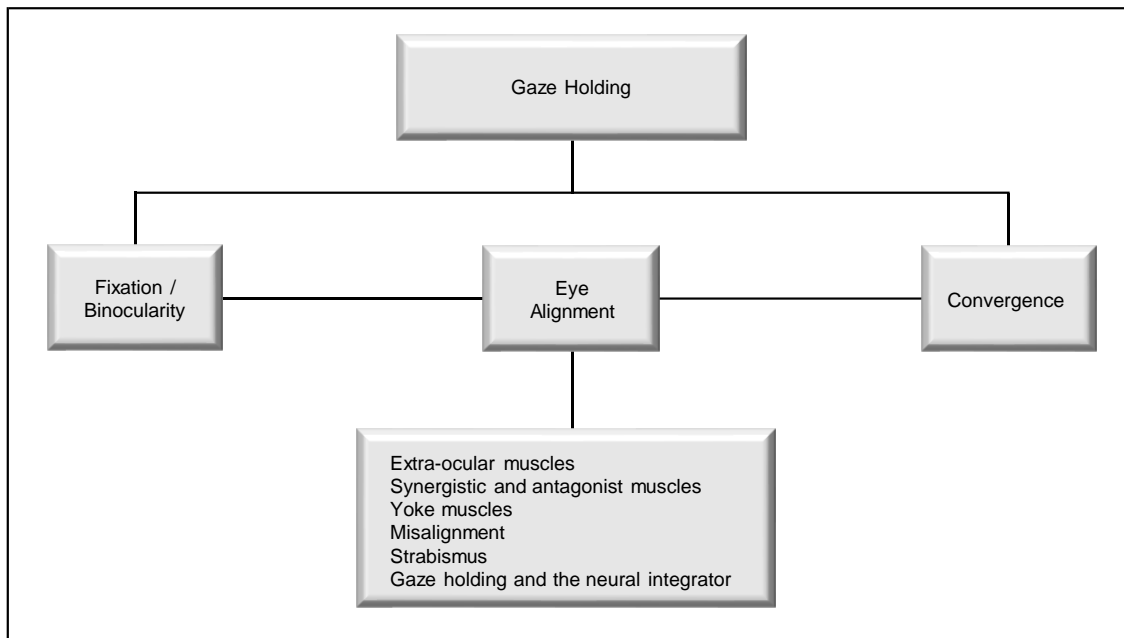


Figure 2.8: Gaze holding: sub-domains and identified items

### 2.9.1 Fixation

The infant begins fixation with monocular vision, since extraocular control of both eyes to gain fusion is not yet possible (Atkinson & Braddick, 2012). The inactive eye either closes or its image is temporarily suppressed or ignored by the brain to avoid a doubled or superimposed image (Atkinson, 2002). Thus, the infant learns to control movements of each eye separately. At first the infant prefers one eye but soon alternates between them. When control of each eye is well established, both eyes begin to integrate, gradually developing binocular vision. The visual fields must

overlap so that corresponding parts of each retina form similar images (Erhardt, 1987). The sensitive period of binocular vision development begins at around 3-months of age (Thorn et al., 1994).

In clinical practice it has been observed that infants with neurological damage seem to look past objects when actually looking toward them. They use eccentric fixation particularly those infants diagnosed with retinopathy of prematurity or other neuronal network damage (Hoyt, 2007). It is thus always important to describe how the infant fixates especially in terms of “Is it stable, unstable or absent”? Also observe if any oscillations are present. No eye turn or head tilt should be noted when fixating. If an infant cannot stop eye movements and fixate, their gaze glides over and past the object of interest. Furthermore, fixation is more regular when the posture is well supported (Hyvärinen, 2013).

The 9 positions of gaze are generally tested as a clinical measurement and assessment of fixation and thus gaze holding (Scheiman, 2011). The clinicians observe the relationships of the eyes as in the various positions of gaze. The 9 gazes are: straight ahead, left, right, straight up, straight down, left and up, left and down, right and up and right and down (cf 2.9.6).

### **2.9.2 Binocularity**

Binocular fixation occurs when the 2 foveas are simultaneously directed toward a particular visual target (Aslin, 1977; Braddick, 1996) with fusion of the retinal images at cortical level allowing for binocularity. The eyes are kept in visual alignment by the coordinated contraction and relaxation of the 6 pairs of external ocular muscles. When the eyes are directed towards a single target and are perfectly aligned binocular fixation results. Binocular vision provides some advantages including enhanced visual acuity, contrast sensitivity, and visual field compared with monocular vision (Atkinson 2002).

Typical binocular vision requires a clear visual axis, sensory fusion and motoric fusion and is key to stereopsis. Normally, stereopsis has a sudden onset between 3-to-5-months of age after which it improves rapidly within a matter of a few weeks (Birch et al., 1985). Stereopsis means that the stimulus can be held on the fovea. The stability of fixation is observed when an infant fixates at a small object or a

penlight (Hyvärinen, 2010). According to Hyvärinen (2010) high contrast pictures can be used on the fixation sticks. It can be colourful with movement and soft sound to elicit fixation. It is also recommended to measure fixation during other tasks such as when an infant fixates on an examiner's face or objects on a table. A fixation stick with a 5 cm face picture on one side and stripes on its reverse side can be used and are based on the work of Robert Fanz, van Loosbroek & Smitsman (1990). Bigger objects do not require exact fixation.

The neuromuscular system of an infant is immature therefore it is not uncommon in the first 2-months of life for ocular alignment, and therefore fixation, to be unstable. Gradually improving visual acuity, together with the maturation of the oculomotor system, allows a more stable ocular alignment by the age of 2-months and thereafter any misalignment should be investigated by an ophthalmologist (Hainline & Riddell, 1995).

Yoked movements of the eyes, in the same direction (versions) and opposite directions (vergences), ordinarily support the achievement of sensory binocularity (Banks, 2018). During fixation of stationary targets, the eyes sustain foveal alignment over a wide range of target locations in the visual field. Gaze direction is controlled by a combination of eye position in the orbit and head position. Gaze is mainly controlled by eye position for targets lying at eccentricities of less than 15 degrees from primary position. Holding eye fixation bigger than 30 degrees without head movements is difficult to sustain and the eye drifts intermittently toward the primary position in gaze evoked nystagmus (Bahill et al., 1975). It has been observed in the clinical practice that infants with poor trunk control due to a neurological insult have a moderate or large tendency of eye turn in, out or up. Infants with asymmetrical postures also present with deviations in the eyes (Scholtz et al., 2013).

In the event of a failure to align the eyes leading to a strabismus, infants may experience confusion in the processing of patterns and the programming of visually directed behaviours such as saccadic eye movements and reaching (Dutton, 2013). Scheiman et al. (1995) reported that a strabismus is a condition in which the eyes are misaligned. A strabismus in which either the right or left eye deviates all the time is called a unilateral constant strabismus. If the right eye and left eye deviate

alternatively, it is called an alternating strabismus. Unilateral constant strabismus can result in amblyopia, which in most cases, is accompanied by a lack of stereopsis and sensory fusion (Banks et al., 1975). If the strabismus is alternating, amblyopia does not develop, and the visual acuity remains normal in each eye since each eye continues to receive normal stimulation (Leat et al., 2009).

No eye turn should be noted in either eye when both eyes are fixating. Good visual development includes eye muscles that control the paired eyes to that team and the two eyes exhibit motor fusion for sensory fusion. Sensory fusion is the blending by the brain of similar images from the area of central vision of both eyes into one composite picture (Leat et al., 2009). For this study strabismus can be categorized in direction and laterality. Table 2.4 defined the different characteristics of strabismus followed by an explanation for each. It is important to give a description of which eye turns, and the direction of turn.

The unilateral and alternating cover measurement is the standard for detecting and measuring an eye turn (strabismus) and evaluating the posture of the eyes or resting position of the eyes when they are prevented from being used together (Hull et al., 2017). According to Hull et al. (2017) in the unilateral measurement, also known as the cover-uncover measurement, the clinician covers the infant's eye with her hand, fingers pointing down, and observes what the uncovered eye does while looking at a near target. Next, the clinician removes the cover and observes both eyes (both eyes should be looking at the target). This procedure is then repeated with the other eye. If there is an outward eye turn (exotropia), the deviating eye moves inward when the non-deviating eye is covered. If there is an inward eye turn (esotropia) the deviating eye moves outward when the non-deviating eye is covered. Eye turning upwards is called hypertropia.

Once a heterotropia has been ruled out as described above, and it has been established that the infant therefore has binocular fusion, one can proceed to the detection of a heterophoria using an alternating cover test method. In the alternating cover measurement, the clinician observes the infant's fixation with a penlight or fixation target when each eye is alternately covered to prevent the eyes from being used as a team i.e., having binocular fusion. The clinician's hand with fingers faced down, is placed over the right eye and moved quickly to the left eye and back to the

right eye. The procedure is repeated, and the eye movements of the eyes are observed. An inward movement of the eye when it is uncovered indicates a tendency for an outward posture or position of the eyes (exophoria) when they are not used together i.e., when binocular fusion is prevented. An outward movement of the eyes when it is uncovered indicates a tendency for an inward posture or position, so called, esophoria (Adler, 2011).

Table 2.4: Characteristics of strabismus

<b>Direction:</b>	<p>Whether the eyes:</p> <p><b>Turn in:</b> Esotropia</p> <p><b>Turn out:</b> Exotropia</p> <p><b>Turn up:</b> Hypertropia.</p> <p>Combination of these is possible and often occur.</p>
<b>Laterality</b>	<p>Whether one eye always turns or if the two-eyes alternate.</p> <p><b>Constant unilateral strabismus:</b> The left or right turns all the time and cause amblyopia.</p> <p><b>Alternating:</b> If the right eye and left eye turn alternately, it is called an alternating strabismus.</p>

### 2.9.3 Eye alignment

There has been long-standing interest in how well young infants align their eyes. Alignment acts as a platform for binocular sensory development (Atkinson, 2002) and is an important sub-domain of gaze holding. The vertical retinal meridians are both upright under binocular viewing condition. The ocular-motor system enhances visual resolution by maintaining alignment of the fovea with attended stationary and moving targets (Westheimer & McKee, 1975). The position of the eye is determined by the equilibrium achieved by the pull of all 6 extraocular muscles (EOMs).

### 2.9.4 Extra-ocular muscles

According to Adler (2011) there are 6 EOMs in each orbit; 4 recti muscles (superior, inferior, medial and lateral) and 2 obliques (inferior and superior). All muscles work

in a coordinated fashion, maintaining significant tension or ‘tonus’ even when the eye is in the primary position and thus presumably at rest. Adler (2011) reported that the precise motor coordination is called motor fusion. Horizontal movements are controlled by the medial and lateral recti which are agonist-antagonist pairs with opposing primary functions; the medial rectus adducts the eye while the lateral rectus abducts the eye. The vertical movements are more complex because the bony orbits are not parallel. The superior and inferior rectus muscles have a more complex effect in the direction of eye movements. In primary gaze, both the superior and inferior recti are angled laterally and approximately 22.5 degrees from the sagittal plane. The primary action of the superior rectus muscle is elevation, but it also adducts and intorts the eye. Intorsion is where the superior pole of the eye rotates medially. The inferior rectus primarily depresses the eye and also adducts and extorts. Extorsion is the rotation of the superior pole of the eye laterally. The superior oblique mainly intorts the eye, depresses and abducts it. The primary function of the inferior oblique is extorsion of the eye, but it also elevates and abducts the eye. For accurate positioning of the visual world on the fovea, the activity of all the EOMs must be tightly coordinated. Table 2.5 summarizes the functions of the ocular muscles, its primary and secondary actions, and innervation.

Table 2.5: Function of the ocular muscles and cranial nerve innervation

<b>Muscle</b>	<b>Primary Action</b>	<b>Secondary Action</b>	<b>Innervation</b>
Lateral rectus (LR)	Abduction	None	CN VI
Medial rectus (MR)	Adduction	None	CN III
Superior rectus (SR)	Elevation	Adduction, Intorsion	CN III
Inferior rectus (IR)	Depression	Adduction, Extorsion	CN III
Superior oblique (SO)	Intorsion	Depression, Abduction	CN IV
Inferior oblique (IO)	Extorsion	Elevation, Abduction	CN III
Lavator palpebrae	Elevate eyelid		CN III

### 2.9.5 Synergistic and antagonist muscles

Asbury and Fredrick (1999) define synergistic muscles as muscles that have the same field of action. The EOMs, like skeletal muscles, show reciprocal innervation of antagonistic muscles. The right medial and left lateral rectus muscles are inhibited when the right lateral and left medial rectus muscles are stimulated. Table 2.6 summarizes the synergistic and antagonistic muscles as described when considering Sherrington's Law (Quaia & Optican, 2011).

Table 2.6: Synergistic and antagonist muscles according to Sherrington's Law

<b>Muscle</b>	<b>Antagonist</b>	<b>Synergists</b>
LR	MR	Superior and inferior oblique
MR	LR	Superior and inferior rectus
SR	IR	Medial and inferior rectus, superior oblique
IR	SR	Medial and superior rectus, inferior oblique and superior rectus
SO	IO	Inferior rectus, lateral rectus and inferior oblique
IO	SO	Superior rectus, medial rectus and superior oblique

### 2.9.6 Yoke muscles: hering's law of equal innervation

For a movement of both eyes in the same direction, the corresponding agonist muscle, in each eye, receives equal innervations according to Hering's Law (Atkinson, 2002). The pair of agonist muscles with the same primary action is called a yoked pair. The right LR and the left MR muscles are a yoked pair for right gaze. The right IR and the left SO muscles are a yoked pair for gaze downward and to the right. Table 2.7 summarises the yoked muscles.

Table 2.7: Yoke muscles in a cardinal position

Eyes up and right	RSR and LIO
Eyes up and left	LSR and RIO
Eyes right	RLR and LMR
Eyes left	LLR and RMR
Eyes down and right	RIR and LSO
Eyes down and left	LIR and RSO

Fixation in the centre and the eight positions of gaze, partly based on the yoked pairs, for testing in a clinical setting is demonstrated in Figure 2.9.

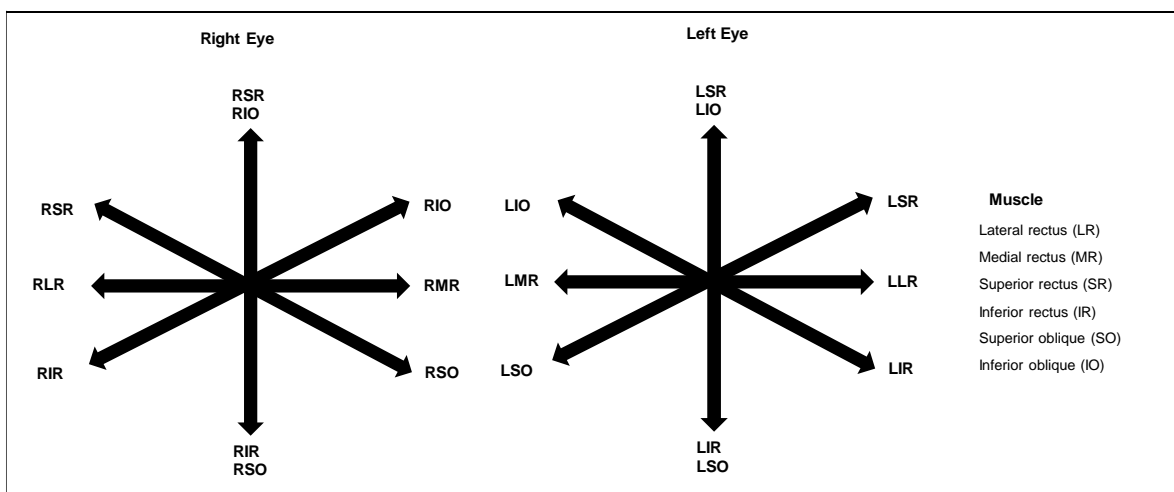


Figure 2.9: Various positions of gaze that are evaluated clinically to assess eye muscle function (Adopted from Scheiman, 1997)

### 2.9.7 Misalignment

If the eyes are misaligned with respect to a binocularly fixated target or even poorly matched in spatial resolution, full stereopsis does not emerge (Shea et al., 1980). Shea et al. (1980) reported that any asymmetrical corneal reflections are an indication that the eyes are not aligned. Misalignment may be in any direction i.e., inward, outward, up, or down. Neonatal misalignment is expected within the first month but generally reduces by 2-months of age as the binocular convergence mechanisms become mature (Thorn et al., 1994). In addition, intermittent pseudo esodeviations are present in the first two-months as the epicanthus can be misleading.

In a longitudinal cohort study of 1150 children, Horwood (2003) found that there was a small but significant association of frequent neonatal misalignment in the first eight weeks with later development of hyperopia and myopia.

In infants between 2- and 21-weeks old, eye alignment is assessed using the Hirschberg measure (Thorn et al., 1994). The Hirschberg measurement detects the presence of an eye turn, whether the eye is turning in or out. The light was jiggled and flashed to obtain the infant's attention and fixation. It was never directed towards his or her eyes for more than a two second period without jiggling or flashing because young infant's orienting response often habituated so that it could be difficult to elicit repeated fixations. The penlight reflection of the cornea should be centred in both pupils during direct reflection with each eye having a centred penlight reflection. The examiner drew the position of the corneal reflections on a pair of drawings for which the observer believed the infants were fixating on the target light. They suggest video recordings provide a more accurate measurement of eye alignment as magnification can be utilized (Hainline & Riddell, 1995). A unilateral eye cover method was successfully used on infants between 4-to-8-weeks to judge binocular fusion which was evident when the infant's fixation did not move when one eye was covered (Stolk et al., 2009).

Hainline and Riddell (1995) found if infants fixate on a target with an off-axis head position, compensations of eye positions will occur. The head position needs to be central with the centre of the infant's head on the same axis as the centre of the target. Infants at one month can align their eyes appropriately for targets at a distance of between 25 cm and 50 cm. Neonatal misalignment may occur before the time that convergence emerges and rapidly cease once vergence becomes reliable at 3-months.

### **2.9.8 Gaze holding and the neural integrator**

Leigh and Zee (2000) reported that to be able to move the eye away from a central point depends on the ability of networks of neurons to integrate velocity signals into position commands. These networks are an accessible system to investigate how the brain holds the eyes steadily in an eccentric position. Holding the eyes steady in a lateral, upward or diagonal gaze position depends on more than fixation. The orbital contents impose elastic storing forces that tend to pull the eyes back to the

central position. To counteract these forces and to hold the eyes steady in an eccentric position in the orbit, the extraocular muscles contract tonically. Such a tonic contraction is achieved by a sustained rate of discharge of the ocular motoneurons.

To understand the neural basis for the gaze holding mechanism, it is helpful to consider the way the brainstem neurons encode eye movement signals. For typical conjugate eye movements, the ocular motor neurons carry a neural signal that contains velocity and position components (Leigh et al., 2015). Such a signal is necessary to hold the eyes steady at an eccentric position in the orbit. The position-coded ocular motor signal (step) is obtained from the velocity-coded signal (pulse) by the process of the neural network, via the neural integrator. For horizontal conjugate eye movements, the nucleus prepositus hypoglossi and medial vestibular nuclei are of prime importance for holding steady, eccentric gaze. For vertical eye movements midbrain structures especially the interstitial nucleus of Cajal, contribute to neural integration. The vestibulo-cerebellum also contributes to the integration of ocular motor signals. Inadequate neural integration causes a progressive decay in the eye position signal and consequent negative exponential to drift the eyes back from an eccentric to a neutral position which clinically manifests as a gaze-evoked nystagmus (Leigh & Zee, 2000).

## **2.10 Convergence**

Convergence refers to the turning inward of eyes when looking at near targets (Erhardt, 1990). The development for binocular vision relates to eye alignment. Without bifoveal fixation, binocular visual functions are impaired. According to Erhardt (1990) bifoveal fixation can be present only when the eyes are manifestly orthotropic i.e., not presenting with any heterotropia. Most typical infants are orthotropic by three months of age, but some do not achieve this until 6- months of age (Archer et al., 1989). From clinical practice it is noted that the bifoveal fixation correlates well with bimanual activities and that at 6-months of age the infant also has the ability to shift a toy from one hand to another while keeping the eyes fixated on the toy. Hand play in different planes of movements assists with bifoveal fixation.

Vergence movements rotate the eyes in opposite directions relative to general laterality to enable binocular fixation of a single object (Gulyás & Roland, 1994).

According to Gulyás and Roland (1994) vergence movements have both gaze holding and gaze shifting properties, meaning that focusing and convergence occur simultaneously and thus the image of the approaching target is kept in the area of sharpest vision in both eyes.

Convergence is related to the ability of the brain to fuse the image of a near object projected in each eye, into a single image. It involves the use of EOMs (more specifically the medial and lateral recti muscles) to direct the visual axis of the two eyes to a near point, involving a simultaneous turning inward of the eyes (Erhardt, 1987). The simultaneous inward movement of both eyes at the same speed is usually an effort to maintain a single binocular vision as an object approaches. During convergence, the gaze may be shifted between targets lying both at different distances and in different directions (Paik & Lim, 2012). Gaze shifting involves a continual re-orienting of the line of sight with stimuli pertinent to current goals via movements of the eye and or head. The evaluation of the convergence system is an important part of binocular vision testing (Paik & Lim, 2012).

Each eye needs to point at a corresponding portion of the visual field to achieve sensory binocular fusion and stereopsis (Aslin, 1977). Fusional vergence occurs when corresponding points on the left and right retinae receive identical images. This happens when the lines of sight of the left and right eye are directed towards a point target. When the eyes look from far to a near point, the eyes need to convergence, and the pupils constrict, and these components are separate in origin but linked together as a common response.

Thorn et al., (1994) explained that convergence involves ocular alignment of both eyes to different viewing distances using binocular information and sensory binocularity. Ocular alignment is important for fusional convergence; therefore, the eyes cannot deviate during convergence. Stereopsis and binocular fusion depend on this ocular alignment during convergence. Convergence depends on neuronal brain network mechanisms that are very similar to those of sensory fusion and stereopsis. Hainline and Riddell (1995), also found that fusional convergence is initiated to provide the fine control of ocular alignment at all viewing distances.

If the infant's eyes have a tendency to drift out, clinicians are clinically interested in the infant's ability to converge. If the ability to converge is not sufficient to

comfortably control the tendency for the eye to drift outward, poor attention, fatigue and difficulty with near tasks can occur (Scheiman, 2011).

Functional binocular convergence mechanisms do not develop until about 3-months of age (Banks, 2018). Thorn et al. (1994) used static targets and found that in infants younger than 3-months eye movements and alignment were better during convergence. They also reported that these infants were markedly symmetrically under-converged when tracking a target moving in-depth but infants by 4-months of age are orthotropic and had good convergence with static and dynamic targets. They demonstrated that by jiggling an illuminated toy approximately 50 cm from the infant's face to attract the infant's attention and moved it slowly toward the bridge of the infant's nose. Infants at 4-months showed full binocular pursuit convergence within 12 cm of the face. The toy used for a fixation target was a brown rubber pony; the face was approximately 2 cm in diameter and contained no fine details. They concluded that there is a close link between convergence and sensory fusion.

Atkinson (2002) used a penlight with a toy on the end to measure convergence in infants up to one year. It was presented at 30 cm from the infant's eyes and is brought toward the child's nose smoothly at around 10-20 cm/sec at 6-months of age the eyes should turn in equally and smoothly as a toy moves closer (Thorn et al., 1994; Hainline & Riddell, 1995). The examiner noted the distance at which both eyes converged and then the distance at which convergence was lost. If an infant suffers from severe convergence insufficiency the infant may have intermittent double vision at their near point of convergence which promotes visual stress influencing near task activities. Failure to converge may related to eye pathology and/or neurological problems (Atkinson, 2002).

## 2.11 GAZE SHIFTING

The domain gaze shifting and sub-domains pursuit, saccades, gaze following, and joint attention is described in this section. In Figure 2.10 the domain gaze shifting with its sub-domains are presented.

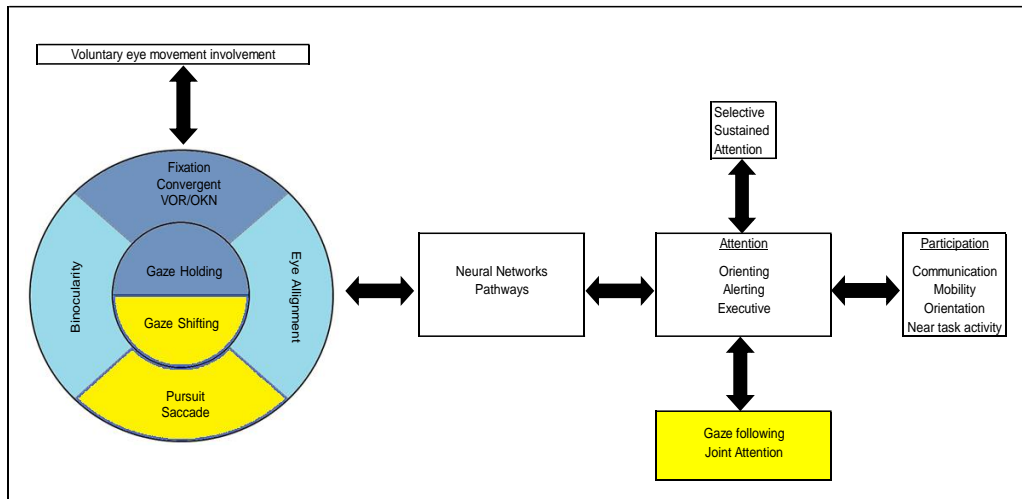


Figure 2.10: Gaze shifting and the relevant sub-domains, pursuit and saccades

Figure 2.11 summarises the sub-domain, pursuit with falls under the domain of gaze shifting, with particular reference to the sub-categories of pursuit namely: smooth pursuit eye movements, gaze pursuit, gaze following and joint attention in 6-to7-months-old infants (Miller et al., 2011). It guided the path taken by the researcher for the development of the VEMMT.

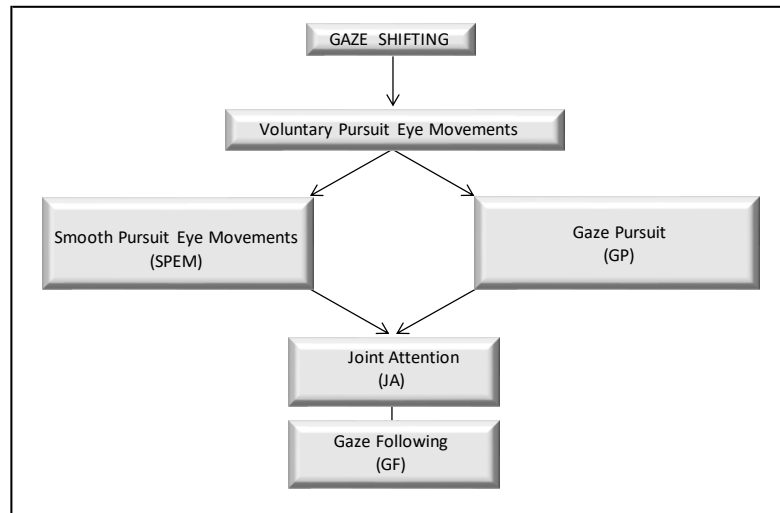


Figure 2.11: Domain: Gaze shifting. Sub-domains: pursuit eye movements. Subcategories: smooth pursuit eye movement, gaze pursuit, and joint attention, gaze following

## 2.12 GAZE SHIFTING: PURSUIT EYE MOVEMENTS

Pursuit eye movements requires an infant to have the ability to maintain fixation on a target and to be able to follow the target as it is moved in different directions (Leat et al., 2009). Infants can usually follow moving objects using voluntary pursuit eye movements. Infants with impaired vision often do not have pursuit eye movements but their movements are composed of irregular saccades (Jacobs et al., 1997).

Eye and head movements are differentiated at 6-months of age. If an infant's eye and head movements are not differentiated, even small eye movements are combined with head movements (Hyvärinen, 2013). In this section, pursuit eye movements are divided into smooth pursuit eye movements (SPEM) and gaze pursuit (GP). This subsection discusses first why SPEM is important in an infants' life, as they may choose to follow moving targets with the eyes alone (SPEM) or by using a combination of eye and head movements which is termed gaze pursuit.

Smooth pursuit is an important part of the visual attention mechanism and enables clear, single vision of objects moving within the environment (Lengyel, 1998) while with gaze pursuit (GP), the vestibular ocular response (VOR) must be negated to follow the movement of the target smoothly (Barnes, 1988). Therefore, based on the clinical experience of the researcher, a discussion of SPEM and its variables separated from GP follows particularly as poor postural and head control can

influence VEMs (Scholtz et al., 2013). Finally, the developmental aspects are discussed with the neural substrates and networking.

### **2.13 SMOOTH PURSUIT EYE MOVEMENTS**

The smooth tracking movements by the eyes alone of an object moving against a stationary background is termed SPEM and is an indicator of visual and foveal maturation in infants (Pieh et al., 2011). This movement allows the eyes to maintain foveal alignment with a moving target that is voluntarily selected (Barnes, 2008).

Natural environments offer a myriad of potentially relevant voluntary pursuit eye movements that involve the:

- amplitude
- velocity and direction of the motion
- stimulus field in which it happens and
- attentional system

Smooth pursuit eye movements refer to smooth tracking movements by the eyes alone without head or posture movements allowing the eyes to maintain foveal alignment with a moving target that is voluntarily selected against a stationary background (Ferrera & Lisberger, 1995). The SPEM is capable of accurately matching the velocity of the pursuit movement to that of a moving target. With the evolution of a fovea and a large ocular motor range, it became advantageous to be able to move the eyes with the head held still. Humans, in general, use saccades to foveate objects of interest quickly and then smoothly track the target with pursuits to stabilize the retinal image of the selected target on the fovea, minimizing the motion blur to process the perception of the moving target (Damasse et al., 2018).

The purpose of SPEM therefore, is to stabilize moving objects on the retina and thereby enable the perception of object details (Pieh et al., 2011). An image or object moving across the retina stimulates eye movements. A typical pursuit velocity is 30-40 deg/sec and has a lengthy latency period i.e., a stationary target that begins to move at a constant velocity will travel a distance before the eye begins to move (Gredebäck et al., 2010). Since pursuit movements are velocity-limited, one or more

saccadic movements are typically used to bring the fovea close to the position of the moving target (Von Hofsten & Rosander, 1997). The pursuit system appears to continuously update the estimated velocity of the moving target and program an appropriate acceleration or deceleration of the eye thereby ensuring the image on the fovea.

The typical control systems approach for characterizing the pursuit system consists of presenting a sinusoidal oscillation of the target, usually in the horizontal meridian of the frontal-parallel plane. This sinusoidal oscillation consists of a target that traverses a constant angular distance (the amplitude of the sine wave) while undergoing a continuous variation in velocity (maximum at the midpoint; zero at two endpoints (Collewijn & Tamminga, 1984). The ratio of the amplitude of eye excursion to the amplitude of target excursion, the ratio of eye velocity to target velocity and the temporal delay of the eye relative to the target are the quantitative characteristics. Adults usually follow an object with a smooth pursuit to inspect its fine details. If such inspection is not necessary, it requires less effort to observe the target using saccadic pursuit or a mixture of saccadic and smooth pursuit (Lengyel, 1998). It has been observed in clinical practice that children with CP do not have smooth pursuits, but movements composed of irregular saccades.

### **2.13.1 The development sequence of smooth pursuit eye movements**

At birth and up to two months of age, tracking of visual stimuli is relatively poor. It occurs only at relatively slow stimulus speeds, and it generally involves saccadic eye movements rather than SPEM (Hainline & Riddell, 1995). Alert new-born infants will follow interesting moving objects with a combination of head and eye movements and if the head is held the eyes track the target by making a series of saccades (Jacobs et al., 1997).

Smooth pursuit eye movements develop by seven weeks of age, depending on the size of the target and at a relatively slow stimulus speed (Aslin, 1981). Stimulation with large targets lead to an increased saccadic frequency or optokinetic nystagmus response (OKN) (Pieh et al., 2011) which is known to be present in new-born infants because of the existence of subcortical, as well as cortical mechanisms (Jacobs et al., 1997). It is apparent that SPEM can be elicited shortly after birth, but these

smooth movements are quite brief, dependent on target velocity and size, and typically interspersed with saccades (Lengyel 1998).

Alert new-born infants will follow interesting moving objects with a combination with the head and eye movements, and when the head is held still the eyes track the target by making a series of saccades (Jacobs et al., 1997). It is therefore important to get the steadiness of the eyes position by attracting the infant's attention and fixation by wiggling the toy or squeaking a toy before eliciting a smooth pursuit.

Smooth pursuit eye movements depend on the size and speed of the tracking object, luminance, position of the target in the visual field, acuity, and contrast sensitivity (Lengyel, 1998). Von Hofsten and Rosander (1997) used a narrow horizontal slit of 1.5 cm wide, 60 cm in height with a moveable happy yellow face 7 cm in diameter with a black contour around it. Between 2- and 6-months of age, there appears to be rapid development in smooth pursuit target tracking (Rosander & Von Hofsten, 2002). At 6-months of age, the speed at which tracking occurs reaches adult levels (Von Hofsten & Rosander, 1997) however, further maturation is slow and still incomplete by the age of 18-months (Pieh et al., 2011). Infants younger than eight weeks of age have SPEM only for targets moving less than 10 deg/sec tracking large targets of 16 degrees (Roucoux et al., 1983), but for target speeds greater than 10 deg/sec, tracking at this age is primarily saccadic (Von Hofsten & Rosander, 1997). Jacobs et al. (1997) found that the trend of a high saccade-ratio in infants during eye movements may be due to immaturity in attentional processing, foveal development, cortical motion processing and inadequate conversion of velocity signals into appropriate oculomotor commands. If the optokinetic nystagmus from birth were absent, it would influence the oculomotor behaviour. The stimuli need to be well-defined contours of high contrast and there are no influences of schematic face, a scrambled face, photographic representations of human faces for SPEM at 6-months of age (Pieh et al., 2011).

Latency is the period from stimulus motion in one direction to the initiation of appropriate eye movements. For increasing stimulus velocity, there was a trend of decreasing latency in infants at 6-months (Jacobs et al., 1997). It was therefore considered appropriate in the current study to use sinusoidal, triangular and circular motions as the smooth pursuit is influenced by the predictability of target motion

(Harris et al., 1993). Atkinson (2002) used a conspicuous target such as a silent, shiny Christmas decoration at least 5 cm in diameter held at a 30 cm viewing distance for infants in the first year of life. The target is slowly moved laterally at 5-10 deg/secs from the infant's midline at eye level. The infant should be in an alert state.

### **2.13.2 Target characteristics in the assessment of spem in infants**

Smooth pursuit eye movements can be modulated by perceptual and cognitive factors such as visual attention (Damasse et al., 2018). Interesting targets such as faces (Von Hofsten & Rosander, 1997), a Mickey mouse face (Roucoux et al., 1983), or circles, "bull's eyes" patterns or faces (Hainline & Riddell, 1995) may elicit SPEM in infants younger than 2-months, whereas simple rectangle targets do not. Moreover, non-predictable target paths are more likely to elicit attention than oscillating target paths (Shea & Aslin, 1990). Horizontal tracking is smoother than vertical tracking (Gredebäck et al., 2010). Hence, it appears that speed, stimulus, size and target path are important considerations when eliciting SPEM.

### **2.13.3 The neural mechanism involved in spem in infants**

The neuromotor commands to rotate the eyeball, to return to, and maintain a steady orbital position depends on the sequencing of the agonist and antagonist firings and are not so effective in early infancy (Aslin, 1977; Richards & Holley, 1999; Shea & Aslin, 1990).

Brain areas related to smooth pursuit include the cerebellum (flocculus, dorsal vermis, and fastigial nucleus), medial superior temporal cortex, pontine nuclei, caudal FEF and supplementary eye-fields (SEF). Since FEF and SEF are known to be involved in SPEM gain (Rosander & Von Hofsten, 2002) the intensive development between 2 and 6-months of age may reflect profound maturation of the frontal cortex during this period. This is consistent with the maturation of other oculomotor parameters including saccadic accuracy and optokinetic symmetry (Harris et al., 1993). In contrast, the sensory system, in particular, the fovea only matures around 11-to-15-months of age. The abducens nucleus is the centre for horizontal eye movements. The abducens nucleus contains two main groups of neurons: motoneurons that send axons to the ipsilateral lateral rectus muscle, and internuclear neurons that project, via the contralateral medial longitudinal fasciculus,

to synapse in the oculomotor nucleus on medial rectus motoneurons (Carpenter & Batton, 1980).

The oculomotor and trochlear nuclei receive inputs for vertical eye movements from the rostral interstitial nucleus of the medial longitudinal fasciculus (riMLF) which lies in the prerubral fields. The interstitial nucleus of Cajal is important for vertical gaze holding. Vertical vestibular and pursuit signals ascend to the oculomotor and trochlear nuclei from the lower brainstem. Rostral interstitial nucleus of the medial longitudinal fasciculus houses most burst neurons for vertical and torsional eye movements; burst neurons for clockwise movements (right eye extorts, left eye intorts) lie in the right riMLF; those for counterclockwise movements lie in the left riMLF (Büttner et al., 1977).

The cerebellum ensures that eye movements and gaze holding are calibrated to provide clearest vision. The vestibulocerebellum, which consists of the flocculus, paraflocculus, and nodules, is important for steady gaze holding, smooth ocular tracking, and optimal performance of the vestibulo-ocular reflex. The dorsal vermis and underlying fastigial nucleus have an important role in programming accurate saccades and the initiation of smooth pursuit (D'Mello et al., 2020).

The primary visual cortex is essential for generating smooth pursuit. The parietal-occipital-temporal lobe junction contains secondary visual areas important for detecting the speed and direction of moving targets in three dimensions, and generating an eye tracking response. This area of the posterior cortex gives rise to an ipsilateral pathway to brainstem and cerebellum, which is important for smooth pursuit eye movements (Tusa & Ungerleider, 1988).

The basic control system for smooth pursuit movements is present at birth, but the actual smooth tracking waits for the development of some related mechanism or the elimination of one or more constraints on the programming of smooth movements. Drowsiness, inattention and poor motivation to perform can be constraints to development. When measuring SPEM the movement of the fixation object should have a constant speed as head movements may compensate for insufficient SPEM (Pieh et al., 2011).

To the best of the researcher's knowledge during the literature research, no assessment, screening, structured observation or measurement tool for typical developing 6-to-7-months-old infants to measure SPEM, taking into account all the above-mentioned criteria currently exist.

## **2.14 GAZE PURSUIT**

Clohessy et al. (2001) divided the visible world into a stationary field or central field of 30 degrees, an eye field for which only eye movements were needed and a head field in which both the head and eyes moved. Thus, while SPEM involves the movement of the eyes only, gaze pursuit is when an infant visually tracks a smoothly moving target using a combination of eye and head movements (Braddick & Atkinson, 2011).

### **2.14.1 The developmental sequence of gaze pursuit**

Regal et al. (1983) showed in their study with neonates that pursuit of a target should be more extensive when the target moves from the periphery to the centre than when the target moves from centre to the periphery. The size of the target was large and salient, the target distance was small, and its velocity was low (10 deg/sec). They also found in the neonates that the central to the periphery movement favours oculocephalic smooth pursuit while periphery to central condition favours ocular pursuit alone.

From birth to the second month of life, considerable changes take place in terms of visual activity including increased participation of the head. This implies greater control of the head motility even before the infant is able to hold its head upright against gravity in sitting. Head control is fully developed by the 6-to-7-months of age with increased cervical spine mobility (Bly & Ariz, 1995). Therefore, it is important to assess the head position during SPEM and gaze pursuit (GP).

### **2.14.2 Neural substrates for gaze pursuit**

Stabilizing the retinal image of a moving target against a stationary background with eye and head movements produce a vestibular signal from the semi-circular canals. The canals are acceleration detectors, but their output is integrated to produce a velocity signal which is conveyed to the ocular nuclei.

The processing of information from the semi-circular canals regarding head movements occur in the vestibular nuclei which then connect directly to the ocular motor nuclei to bring about eye movements to stabilize vision of a stationary target during head movement by means of the VOR. These pathways from the vestibular nuclei in the medulla to the pons and midbrain pass in several fibre tracts including the medial longitudinal fasciculus. However, the VOR needs to negate when following a moving target and thus during the elicitation of pursuits. Abnormalities of head posture may be caused by a disturbance of vestibular function (Guitton, 1992). Incorrect gaze pursuits will indicate dysfunction in VOR or head stability.

### **2.14.3 The influence of visual field on gaze pursuit**

The VF of the infant depends on the distance at which the target is presented. At 4-months of age, the infant can switch attention to an interesting new target meaning that the infant can disengage from a fixation point. A rapid expansion of visual field size occurs at 6-months of age and then continues at a slower rate up to the age of 12-months.

Pratesi et al. (2015) found, in infants ranging from 4-to-10-months, that stimuli at 30 degrees of visual field seem to be visually detected using mainly eye movements, while for larger fields (60 degrees), at a distance of 60 cm from the target, a compensatory head movement is required pending on the task.

The ability to follow gaze, the head and eyes of another person, is an important prerequisite for joint attention (Lunghi et al., 2020). Cues to other people's attention direction depends on the direction of both the head and eyes. In the following section gaze following will be discussed in its relation to joint and sustained attention and its role in communication with social interactions in a 6-to-7-months-old infant.

## **2.15 JOINT ATTENTION**

Attention sharing often involves gaze following or gaze shifting to intersect with another person's direction of gaze (Thorup et al., 2016). Attention sharing skills facilitate not only language and action but also learn and support the capacity to infer others' mental states (Deák et al., 2014). Joint attention (JA) episodes are counted when mutual engagement with an object or activity reaches a criterion duration of at least 3 s (Bakeman & Adamson, 1984; Vaughan Van Hecke et al.,

2012). Joint attention has been defined as the triadic coordination of attention between oneself, a social partner and an object, event, or symbol (Bakeman & Adamson, 1984).

Before language acquisition and before infants can grasp, crawl, or stand, gaze serves as the infant's central mode of communication. Social engagement depends on shared gaze signalling, a willingness to interact with gaze breaks defining the termination of social engagement (Harel et al., 2011). Pre-term infants tend to be slower in showing preference to a novel visual stimulus and require more exposure before novelty preference is established and are less efficient in disengaging attention from stimuli (Rose et al., 2001).

Infants, therefore, develop the capacity to follow the gaze of others, allowing joint visual attention to facilitate language acquisition and cognitive development. The ability to coordinate visual attention with a social partner appears especially important to early language learning (Senju et al., 2015).

Joint attention is often referred to as a milestone in social cognitive development, language acquisition and in emotional regulation allowing infants to partake in social interactions and follow the gaze directions of others (Gredebäck et al., 2010).

### **2.15.1 Cortical networks of joint attention**

Responding to, and initiating JA involves cortical networks (Mundy, 2016; Mundy & Newell, 2007). Responding to JA refers to the infant's ability to follow the direction of the gaze or gesture of others to share a common point of reference. Initiating JA involves the infants' use of gestures and eye contact to direct the attention of others to objects, events and themselves, and to show spontaneously, or seek to share an interest or pleasurable experience with others (Mundy & Newell, 2007).

The neural substrates that function to respond to JA involve the posterior parietal association areas, superior temporal cortex and the parietal, temporal and occipital association areas or the so-called posterior attention system (Posner et al., 2014). A shorthand of expressing for the posterior attention neural networks are that the individual's understanding is that "where others' eyes go, their behaviour follows." The anterior attention system involves the FEF, prefrontal association cortex, dorsal anterior cingulate and orbital prefrontal association cortex and can be characterized

as “where my eyes go, my behaviour follows” such as seeing an object, reach for it and then grasping it (Posner et al., 2014).

Initiation of JA also involves alternate looking by first looking at an object, making eye contact with another individual to share the attention of the object and then look at the object again. In the clinical practice, it has been observed that many parents do feel despondent as their infants do not react to their social cues and play. These social cues do correspond closely with gaze shifts, gaze holding and with other visual functions such as acuity, contrast and visual field (Yu & Smith, 2013). In clinical practice it is therefore important to treat holistically and not only the eye movement without a goal-directed action. Therefore, initiating and responding to JA should be highly correlated with eye movements.

In daily life, infants are exposed to many opportunities to respond to their parents’ direction of gaze to increase the likelihood of attending to the correct object in incidental novel opportunities. Cueing of an object through gaze following enhances object processing (Cleveland et al., 2007). Gaze following or shifting gaze to intersect with another person’s direction of gaze is important for the development to share or JA by 6-months (Gredebäck et al., 2008) as long as it involves one salient object to prevent additional distractors (Triesch et al., 2007). Senju and Csibra (2008) found that 6-month-old infants followed the adult’s gaze toward an object only when ostensive cues such as direct eye gaze and infant-directed speech precedes the gaze following. This behaviour serves as a role in assisting an infant to respond effectively to preferential communication directed to them with gaze following appearing to reflect the expectations of a more active, communicative role from the information source. Attention-grabbing cues such as direct gaze of an infant, infant-directed speech, lifting eyebrows, intonation and name-calling, modulate attention early in life. Gredebäck et al. (2018) questioned whether infants only follow gaze in contexts of ostensive cues, or whether gaze following can be observed in other contexts that do not include ostensive communication. They found that gaze following is not limited to a particular set of ostensive cues but can occur in a multitude of contexts and concluded that perhaps young infants learn from what we do, not from what we intend to communicate.

Infants receive adequate naturalistic input to learn an association between their parent's gaze direction and the location of interesting sights by watching how adults manipulate objects. Infants strongly prefer watching their parents manipulate objects during naturalistic face-to-face play and object movement attracts an infant's attention (Deák et al., 2014). Deák et al. (2014), found in their video-based behavioural analysis of the naturalistic parent-infant play, that adults tend to look at things that infants find interesting, and that infants could learn by noticing this tendency. When caregivers looked away from their infant to attend to their object-handling, the infant will look towards the caregiver while the caregiver looks at her own hands while manipulating objects, then the eyes of the infant will shift towards the caregiver's hands. In this way, infants receive adequate naturalistic input to learn associations between their caregiver's gaze direction and the locations of interesting sights. This opportunity ensures that infants will have enough input to form an abstract association of different gaze directions. Their results suggest that infants could learn gaze following in the course of event sequences that naturally occur during dyadic interaction with caregivers to learn a complex social skill. When infants' manipulative skills improved, infants attended progressively less to mother-held objects and more to self-held objects.

## **2.16 GAZE FOLLOWING**

The ability to look where somebody else is looking is called gaze following and is a foundational component of the social interaction and perceptual-attentional abilities in humans (D'Entremont, 2000). Gaze following is attention sharing behaviour (Triesch et al., 2007) and is a fundamental element of face-to-face interactions, a precursor to language development (D'Entremont, 2000) and part of the inter-relationship between perceptual-cognitive and social development (Bakeman & Adamson, 1984). Spontaneous gaze shifts in the direction that the mother attends to (or moves her gaze towards) will often result in interesting sights. This reward is assumed to strengthen the tendency to look in the same direction as the mother (Triesch et al., 2007). Before following another person's gaze, attention-getting or sustained attention is necessary.

Given an infant's innate sensitivity to stimuli with eye-like features, eyes are the most relevant point of fixation on a face and thus a starting point from which gaze following

occurs (Tenenbaum et al., 2015). However, disengagement from the eyes may also be more likely when the adult's gaze is averted as it is less salient stimuli (Hood & Atkinson, 1993).

Gaze following can be linked to imitation as the behaviour being observed is another's gaze shift to a particular location in space, and this behaviour is replicated (Tomasello et al., 2007). However, according to a stricter definition for true imitation, gaze following is rather a form of response facilitation because the copied behaviour, a gaze shift to a certain location, is not novel but already part of the infant's repertoire (Schaal, 1999). Kumashiro et al. (2003) found that gaze following emerges in a similar way, and for similar reasons, as the emergence of other imitative behaviours. The link between gaze following and imitation implies that the neural basis of gaze following may be closely related to the neural basis of other imitative behaviours (Triesch et al., 2007) such as mirror neuron system. The defining characteristics of mirror neurons are that they become activated when the person acts, such as reaching or when the person sees another agent perform the same or a similar action (Rizzolatti & Craighero, 2004). Mirror neurons may play a role in many social-cognitive functions, including understanding the actions of others, imitation, intention understanding, and empathy (Rizzolatti & Sinigaglia, 2016).

The direction of both the head and eyes provides cues to the direction of the other person's attention (Thorup et al., 2016). Hence, gaze following emerges early and is influenced by the properties of the target objects, the interaction partners and the infant's eye movement responsiveness with its characteristics (Del Bianco et al., 2018). Gaze following emerges through the spontaneous organization of processes within the individual, the child's behaviour, and the environment in which he/she acts (Smith & Thelen, 2003). Infants have learned that turning their eyes cued by the adult's head turn, produced a visually interesting result and already at three months of age they can follow another person's gaze (Hernik & Broesch, 2019). Therefore, gaze following is a good functional candidate to track atypical development (Del Bianco et al., 2018). Furthermore, impaired gaze following is a defining feature of autism spectrum disorder (Mundy, 2016). It can be constrained by perceptual-attentional factors and is dependent to some degree on environmental support (D'Entremont, 2000). Additional cues such as pointing and verbalization increase

not only gaze following but also attention to the social partner, especially if the child requires the additional motivation to focus on the source of cues.

### **2.16.1 Development of gaze following**

Early in life, infants can align their gaze with the gaze of others, and through this process, attend to the same events and objects as other people. The ability to follow gaze is an important prerequisite for JA. Sharing attention through gaze following contributes to the maturation of the frontal cortical areas and executive functions (D'Entremont, 2002). One interesting aspect of executive function is that sharing attention through GF may contribute to and enhance neural circuitry networking (Del Bianco et al., 2018).

### **2.16.2 Gaze following emergence**

Gaze following emerges between the ages of two- and four-months and is relatively stable after 6-months, elicited by head-eye direction and motion (Corkum & Moore, 1998; Rizzolatti & Craighero, 2004). In structured social interactions, the latency of gaze following (the time from the onset of the adult's gaze to the onset of the infant's shift to the same direction) is about 3 s at 3-months of age to slightly more than 1 s at 8-months of age (D'Entremont, 2002). It is more pronounced at 6-months of age but not always precise because the direction of the head movement prevails in directing an infant's attention that is different from gaze cueing. D'Entremont (2000) study was performed live and are of particular importance in the current study.

Farroni et al. (2004) found that new-borns orient to targets that appear in the direction cued by eye gaze. Visual cueing by using eyes and the head is therefore important for gaze following at 6-months of age (Triesch et al., 2007).

Infants younger than 12-months rarely follow gaze to objects outside their visual field of view, such as looking behind them (Corkum & Moore, 1998). It is understandable as the infant's plane of movements in the transverse plane still needs refinement with the necessary balance reactions in sitting at 6-months of age (Scholtz et al., 2013). Target distance from the middle of the infant's visual field is a critical factor for early gaze following, and infants at 6-months of age tend to look at the first target they encounter.

Six-month-old infants can follow the direction of an adult's head turn to a moveable and stationary target at 10 and 25 degrees from the midline that is within their visual field (D'Entremont, 2000). Therefore, it is suggested that less strict criteria be used for 6-month-old infants as gaze following is stable but not well developed compared to older infants. Six-month-old infant's participation to gaze following depends on the stationary or moveable target's placement. It needs to be close to their midline.

Gredebäck et al. (2018) stated that gaze following occurs in a variety of contexts, some of which involve ostensive cues, whereas others do not. They found infants can follow others' gaze and thus have the opportunity to learn from others, not only in tutoring contexts but also in situations that were not specifically intended for learning. This suggests that with sufficient power even a simple shift of head and gaze is enough to elicit gaze following. They concluded that gaze following responds well with direct gaze followed by a head shivering action of an examiner for attention grabbing. Table 2.8 summarizes areas of importance in relation to gaze following and attention to be taken into consideration during the development of the VEMMT in the current study.

Table 2.8: Areas of importance for gaze following and joint attention

<b>Areas of importance</b>	<b>For consideration</b>
<b>Procedures</b>	A trial includes a period of interaction to attract the infant's attention to the adult's face that lasts for at least three seconds. The adult moves her head and eyes congruently from a central location toward one of two targets placed symmetrically on either side of her. The overt gaze shift by the adult is considered to be motivated by the direction of the adult's gaze.
<b>Targets</b>	Puppets or interesting toys or objects in the context of salient but not overly interesting moveable, single or multiple objects. A toy can be handheld or placed on a stand. Be careful of animal faces as it might be seen as a threat. Place a target in the visual field of 10 to 25 degrees. For toy play, place the toy within reaching distance.
<b>Posture/environment</b>	Placement of the adult's hand on the child's trunk is to provide stability but not limiting rotation when turning to follow the gaze of the adult. Keep the child on an adult's lap will cause too many disturbances when taking the infant away from the mother. Place the camera on the opposite side of the materials.

## 2.17 GAZE SHIFTING: SACCADES

Gaze holding has another important sub-domain namely saccades. Figure 2.12 summarizes the domain gaze shifting, with emphasis on saccades, its sub-domain and sub-categories.

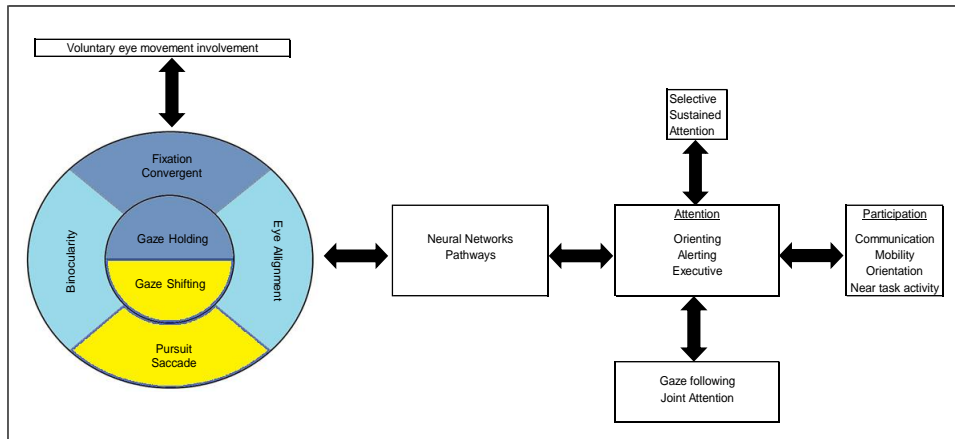


Figure 2.12: Domain gaze shifting with sub-domain saccadic eye movement

Figure 2.13 summarizes the path taken for the identification of sub-domain, saccades, and related sub-categories.

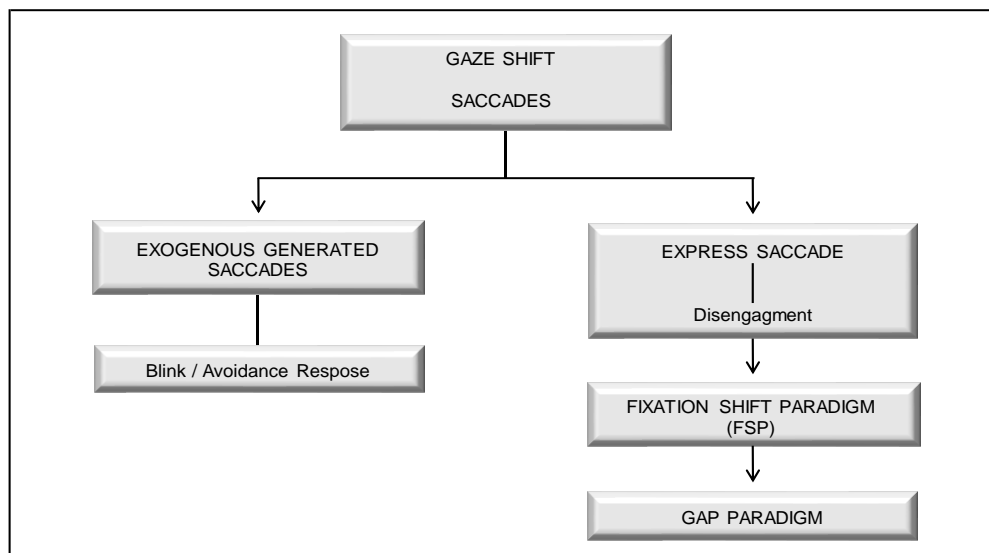


Figure 2.13: Summary of the domain gaze shifting, sub-domain saccades and related sub-categories

### **2.17.1 Purpose of saccades**

Saccades are rapid conjugate eye movements that shift the line of sight between successive points of fixation so that the point of interest will be seen with the foveal centre of the retina (Leat et al., 2009) where the visual acuity is the highest (Bringmann et al., 2018). Kenward et al. (2017) define saccades as an abrupt and rapid eye movement serving to direct the dense photoreceptor centre of the visual field, the fovea, at a target. From birth, new-borns can target objects using saccades; however, although the speed of eye movements during saccades in young infants is no slower than in adults, the latency to react to a stimulus by beginning a saccade varies greatly to infant age and the situation. Saccades are often abnormal in children with motor problems, especially in children with cerebral palsy (Hyvärinen & Hyvärinen, 1983). Saccades are being used efficiently to examine the relationship of parts with the whole. Saccades are important when examining a face, new toys or taking in the details of a new environment (Yue, 2000). These saccades are quick, both large and small, moving in a variety of directions and returning repeatedly to a reference point or points to form a “scheme” (Hyvärinen, 2013). Saccades are often easier to perform by means of two penlights with coloured caps on them which are often the only targets that interest infants (Hyvärinen, 2013). It has been observed that children with CP have the greatest difficulties in controlling their eye movements when crossing the midline. The eyes may be briefly closed at midline or there is a jerk in the saccade. Vertical and horizontal saccades need to be measured as it is revealed that vertical saccades are more regular and can thus be used for reading (Ayton et al., 2009).

When saccadic eye movements are used for re-fixation, the amplitude of the initial saccade is close to that required to bring the image of the new object of interest onto the fovea. Often a small corrective saccade is required for accurate alignment pending on the object’s size and detail (Leat et al., 2009). When assessing VEMs in a clinical setting, the environmental condition influences the outcome. In a clutter visual environment, the suppression of irrelevant non-target information relying on attention is necessary for avoiding saccadic landing errors. Landing errors are found in cluttered visual environments (Hyvärinen, 2010), resulting in confusion in infants with neurological deficits (Fischer & Breitmeyer, 1987; Philip et al., 2016).

Decluttering is, therefore, necessary by spacing out objects or pictures (Hyvarinen, 2010).

The initiation of saccades depends on a “pulse” of increased phasic firing of excitatory burst neurons in the brainstem (Termsarasab et al., 2015). A tonic “step” is required in order to keep the eyes in the intended position and overcome the elasticity of the orbital tissues. A fundamental eye movement function is the so-called eye position neural integrator (NI), which is needed for saccades and pursuits. Full coverage of the anatomy and physiology of vertical and horizontal saccadic centres are beyond the intended scope of this research. Horizontal and vertical neural substrate for saccadic generators is different and need to be clinically separated. As infants cannot shift eyes voluntary on command from one target to another the saccadic visual behaviour can rather be observed by a target that appears unexpectedly in the peripheral scene such as wiggling finger or a shiny light (Termsarasab et al., 2015).

Saccades include a range of behaviours that encompass voluntary shifts of fixation, exogenous saccades that are generated to novel stimuli, quick phases of vestibular and optokinetic nystagmus, and the rapid eye movements that occur during rapid eye movement (REM) sleep (Zhou & King, 1997). Saccades are also important during visual searching. Saccadic eye movements consist of the most rudimentary of all saccades, the quick phases of the VOR and OKN, through to exogenous overt-spatial orienting saccades made in response to the sudden appearance of a novel visual stimulus, and finally to a higher-level volitional behaviour such as saccades directed toward the remembered location of a visual target. In clinical practice, if voluntary saccades cannot be generated, it is useful to elicit the quicker saccades elicited by the novel stimuli or the quick phase of the OKN or VOR (Lencer & Clarke, 1998).

Saccades that are closely coupled with visual attention include a range of behaviours that encompass voluntary shifts, rapid response to a novel stimulus suddenly appearing and higher-level orienting volitional saccades and will be included in the newly developed VEMMT (Hessels et al., 2016). Table 2.9 summarizes the sub-categories of saccades and definitions.

Table 2.9: Definition of the sub-domains of saccades

<b>Sub-category</b>	<b>Definitions</b>
<b>Exogenous Saccades</b>	Saccades generated to novel stimuli that unexpectedly occur with the environment.
<b>Express Saccades</b> <ul style="list-style-type: none"> <li>- Fixation shift paradigm (FSP)</li> <li>- The gap paradigm (GP)</li> </ul>	Very short latency saccades that can be elicited when the novel stimulus is presented after the fixation stimulus had disappeared

### 2.17.2 Exogenous generated saccades

Exogenous saccades are made to novel stimuli (visual, auditory, or tactile) that unexpectedly occur within the visual environment. Exogenous orienting usually involves salient objects that appear suddenly in the visual field and capture attention with gaze shifting. It occurs during a strong stimulus-driven movement that interrupts attention from its current focus and triggers a saccadic eye movement to a peripheral stimulus (Dannemiller, 1998). Exogenous shifts orient infants to a salient stimulus to foveate an object in a visual field that is mediated mainly by the superior colliculus and frontal eye fields (Farroni et al., 2000; Ross-Sheehy et al., 2015; Hunnius, 2007). Random failures on the part of the infant to orient to a strong stimulus might be attributed to slow modulations of alertness (Dannemiller, 1998).

Exogenous orienting probably involves competition between different potential targets of attention, and also demonstrates that goal-directed control is not always able to override exogenous saccades driven by abrupt-onset stimuli in the visual scene (Hoang Duc et al., 2008). Ultimately the eyes must be aligned and move together to one, or another location in the visual field (Sheinberg & Zelinsky, 1993). These movements involve decisions about how long to continue looking at the interesting object, its location, and where to look next. Infants as young as 1-months of age can shift their gaze to a target that appears suddenly in the central and peripheral visual field. Overt orientation response depends on the physical characteristics of objects, such as the size, contrast and luminance (Scholz et al., 2018).

### **2.17.3 Avoidance blink response to an exogenously generated response**

Infants aged between 6- and 20-days already show an adaptive avoidance response guided by the vision to approaching objects, to discriminate spatial variables mediated by motion pending on the closeness, size if it is goal-directed, or speed of approach (Bower et al., 1971). Infants were shown two foam-rubber cubes, one measuring 20 cm per side and the other measuring 50 cm per side, which were placed on table 75 cm away from the infant sitting at the end of the table. Each of the objects was moved toward the infant at a constant speed (15 cm/s) and stopped at 20 cm (far approach) or 8 cm (near approach) from the infant's face. Infants were placed upright, as it encourages a wakeful state in a supportive chair that supports the posture but leaving the arms free. The intended design of the experiment consisted of four trial conditions: small object/far approach, large object/far approach, small object/ near approach, and large object/near approach. Both the near-approached conditions caused so intense upset that the infant's eyes opened wide, their heads went back, and their hands came up between the object and face as if they tried to protect themselves from the collision while the eyes remain straight ahead. There was a slight delay in the blinking response. A rapid hand as a target was used by (Erhardt, 1990) and found the response to a visual threat becomes immediate and consistent by blinking at 5-months of age, in the central and peripheral field.

From birth onwards, infants explore their environment visually by shifting their gaze across different locations primarily with the use of saccades (Hunnius & Geuze, 2004). Typically, infants at 1-month of life can shift fixation from a central target to a salient target that appears suddenly in the periphery due to the sub-cortical systems. It will only be possible if both targets are not visible simultaneously, and when there are no visual or auditory distractors in the rest of the visual field (Braddick & Atkinson, 2011).

### **2.17.4 Express saccades**

Attention may operate without saccades, but saccadic eye movements depend on attention. This study did not intend to measure visual attention in infants but rather to identify VEMs in the attentional paradigm. Express saccades occur from central into peripheral visual field to foveate an object of interest (Zhao et al., 2012).

Orienting within the visual field is one of the earliest functions to emerge in infancy (Fischer & Breitmeyer, 1987). Continuous eye movements to look from one point to another in the visual field during daily life are observed in typical developing infants.

Voluntary eye movements may be made without the appearance of a new stimuli and seem to be driven by an internal searching or scanning process for a particular part of the object or the object itself. These are called endogenous intentional covert attentional orienting, indicating an internal goal-directed mechanism is operated (Zhao et al., 2012).

Not all the main characteristics of saccades, namely, velocity and duration; waveform and trajectory; reaction time or latency, and accuracy, are included in this study due to its extent. Some ingenious saccades-paradigms are included in this study for the development of the VEMMT to measure aspects of saccadic responses to visual stimuli in infants 6-months of age. Attention is necessary for the control of saccades and is stimulus driven. The ability to shift gaze to an object depends on if the infant can disengage before shifting to a next target. Fixation shift and gap paradigm will be discussed.

## **2.18 FIXATION SHIFT PARADIGM**

In a FSP task infants are initially shown one stimulus in the centre. When the infant fixates on the central stimulus, a second target appears in the periphery. The central stimulus either remains visible (competition condition) or disappears at the onset of the peripheral target (non-competition condition). For typically developing infants up to 3-months of age to disengage and shift attention the time required is much longer in the competition than in the non-competition condition (Atkinson & Braddick, 2012).

Switching attention under competition involves disengaging from the current stimulus, followed by a shift of attention, monitored as a saccadic gaze shift eye movement to the new target. In infants who had undergone hemispherectomy to relieve intractable epilepsy, the role of cortical systems in disengagement and attention shifts was confirmed by Atkinson and Braddick (2012). Infants with one cerebral hemisphere can make fixation shifts under non-competition to both sides, where the central fixation disappears at the onset of the peripheral target. Under

competition where the central target remains visible, infants cannot make fixation shifts, to a target appearing in the half-field corresponding to the surgically removed hemisphere. Atkinson and Braddick (2012) concluded that automatic engagement with a target only involves subcortical pathways, whereas cortical control becomes necessary for disengagement from a current central stimulus. The cortical system begins to play a role enabling infants to disengage attention from one visual object of interest and foveate a newly appeared target. The developmental sequence for engaging and disengaging becomes clear. Developmental progression is taken as indirect evidence that in the first months of life, with competition conditions. This reflects activity in subcortical networks involving the SC, with cortical control emerging at around 3-months of age, allowing the infant to shift attention more flexibly at older ages.

This FSP is a predictive and indicator of neurocognitive outcome in children with perinatal brain damage. It includes focal lesions, hypoxic-ischaemic encephalopathy or perinatal abnormality of white matter associated with very preterm birth and siblings of autistic children. It has also been used successfully to assess attention with other aspects of visual-cognitive development in children with West syndrome and Williams Syndrome (Atkinson, 2002).

## **2.19 THE GAP PARADIGM**

Farroni et al. (2000:175) explain the gap paradigm as follows: “The gap paradigm demonstrates the interaction between covert attentional processes and saccadic control. The reaction time to make a saccade to a peripheral target is significantly faster when a central fixation point goes off, shortly before another target is presented (gap). The reaction time will be slower or not even present if the central fixation stimulus stays on (‘overlap)”. In the gap paradigm, there is a time interval between the central stimulus disappearing. The time until the first saccade towards the peripheral target provides a measure of the infant’s ability to switch eye shifts with attention. The gap task is used for visual orienting response and takes overt eye movements as an indicator of attention. The gap task was designed to assess an infant’s ability to disengage attention from a salient central cue in favour of new peripheral input.

As stated by Farroni et al. (2000) disengagement from a central fixation point is a prerequisite for the initiation of a saccade, directing the fovea towards another target. Both the attentional and eye movement control hypotheses are involved. According to the attentional hypothesis (Posner et al., 2014), when attending to a target, saccades to peripheral targets are suppressed. To be able to perform a saccade from one target to another requires that attention needs to be disengaged from the starting location before the eye movement begins. During fixation with engagement, the saccadic system has to be suppressed, causing a delay in reaction time. When a temporal gap is introduced by setting off the central stimulus and setting on a peripheral target, attention is automatically disengaged.

According to the eye movements control hypothesis, the SC is critical for saccadic control (Johnson, 1990). The SC can trigger saccades if the saccadic generation circuit has been partially disinhibited at the time of the target appearance. This disinhibition occurs during the gap when no stimulus is present in the visual field. The gap effect also acts as a warning signal, allowing the subject time to prepare a response. Infants between 1- and 4-months, and especially at 2-months, appear to be forced to fixate at a centrally presented stimulus and have great difficulty in moving their eyes from it to another target in the periphery. Due to the development of an inhibitory pathway to the SC from the primary visual cortex, through the substantia nigra and basal ganglia, disengagement is possible and reflects the maturation of parietal and frontal cortical structures. All pathways have different stages of maturation before reaching the adult stage. Subcortical visual structures are relatively mature at birth compared with cortical structures (Atkinson, 2000).

Visual development represents a transition from a system predominantly controlled by mature subcortical structures to a system dominated by cortical visual functions (Atkinson et al., 2008). This view is supported by Hadders-Algra (2000) who stated that the initial phase of development is primarily dominant in sculpting the developing nervous system, followed by the second phase of development in which movement variation begins at function-specific ages.

Grossmann et al. (2013) have proposed the following developmental pattern for the eye movement control hypothesis during the gap paradigm. At birth, saccades are predominantly driven by subcortical structures. At 1-month of age, when the infant

is fixating on a central stimulus, the SC is prevented from initiating a saccade to a peripheral stimulus because of the inhibition by the substantia nigra. After 1-month of age and still evident at 2-months-of age sticky fixation declines owing to increasing cortical control over saccades. After 4-months of age, cortical mechanisms play an increasingly important role in guided saccades. Sticky fixation wanes by about 4-months of age. Farroni et al. (2013) investigated the gap and overlap effect by using a flashing light as a fixation stimulus in the central field and a schematic face shown at different degrees in the peripheral visual field to determine the saccadic reaction during the gap and overlap stimulus. The testing took place during the hour preceding the scheduled feeding time if the baby was awake and in an alert state. In the first experiment, the latency and direction of the first eye movement away from the centre towards the peripheral target were recorded.

## **2.20 THE INTER-RELATIONSHIP BETWEEN SACCADIC AND ATTENTIONAL SYSTEM**

Saccades are neither necessary nor sufficient for the control of attention. Attention may operate without saccades, but attention is necessary for the control of saccades. You can have an attention shift without any eye movements. When specific properties in the visual environment determine what is selected, regardless of the observer's goal or intention, the selection is said to occur in a stimulus-driven manner (Hoang Duc et al., 2008). A stimulus-driven manner transforms complex visual input into a spatial map of visual conspicuity (Kooiker et al., 2014). Saccades generated to salient objects that appear suddenly within the visual field capture attention even if they are irrelevant (Salinas & Stanford, 2021).

### **2.20.1 Saccadic latency**

Saccade latencies have been found to differ between gap and overlap paradigm conditions, being shorter when there is a time delay between the central target disappearing and the peripheral target appearing and is highest in the competition or overlap condition (Farroni et al., 2013).

Attentional disengagement is important for successful interaction with our environment. Disengagement from a central fixation point is a prerequisite for the initiation of a saccade directing the fovea towards a peripheral target. Saccadic

reaction time is reduced if a temporal gap is introduced between the disappearance of the central fixation point and the appearance of the new lateral target meaning the saccades are more express. Express saccades, a sub-domain of saccades that will be discussed later have a very short latency and can be elicited when the novel stimulus is presented after the fixation stimulus had disappeared. The cortical system begins to play a role enabling infants to disengage attention from one visual object of interest and foveate a newly appeared target. The disengagement of visual attention in the gap paradigm is commonly used in assessments. Poor disengagement under competition, is possibly indicative of delayed or abnormal cortical maturation (Termsarasab et al., 2015). Termsarasab et al. (2015) suggested the measurement of accuracy of vertical, diagonal and horizontal saccades according to its anatomical substrates to determine if eyes move accurately to the new target during a saccadic movement. The range of motion during the shift and disengagement of saccades needed to be observed in all primary eye positions to determine if there are limitations in the range of motion. In clinical practice it has been observed that infants often employ head thrust with extension or eye blinks to generate saccades and these features may be the sole clinical sign indicating a mild defect in saccadic initiation. Delayed initiation of saccades, also called prolonged latency, is seen in neurological conditions.

Saccadic intrusions are abnormalities of ocular fixation involving spontaneous unwanted saccades on regular fixation of a target. These intrusions are often provoked by gaze shifts. It should be noted if saccadic intrusion is present during smooth pursuit and during saccadic shifts. The detection of saccadic intrusion is to have the infant look in extreme lateral gaze and then back to the centre as seen with the FSP (Kulke et al., 2015).

### **2.20.2 Disengagement**

Disengaging from and shifting gaze to, a salient stimulus is a prerequisite for early exploration, reaching, and communication (Hunnius & Geuze, 2004). The efficiency of disengagement increases during the first few months after birth. To be able to direct the fovea from an attended central target towards a peripheral target, disengagement of perceptual attention from the central fixation target must be initiated (Farroni et al., 2000).

Infants between 1-and 3-months of age may show long periods of staring and have difficulty in disengaging from an object or stimulus they are attending to. This behaviour was described over the years differently. Stechler and Latz (1966) named this behaviour “obligatory attention” while others noticed that infants seemed ‘stimulus bound” or “overwhelmed, “glued to the pattern (Cohen, 1972) or “sticky fixation” (Farroni et al., 2000). The phenomenon of obligatory attention seems to occur between 1- and 3-months of age especially at about 2-months of age wherein infants appear to be compelled to fixate a centrally presented stimulus and have difficulty in moving their eyes from the centrally presented stimulus to a peripheral one (Kulke et al., 2015).

Obligatory attention can also be interpreted, however, as a deficit in the ability to disengage from a central target; inhibition of peripheral orienting due to inhibition of the SC by the substantia nigra (Johnson, 1990) immaturity in cortical parietal, middle temporal and frontal systems that control disengagement of attention (Posner et al., 2014).

Attentional processing early in life improves as it becomes easier to disengage from a target and elicit a gaze shift, particularly if more than one target is in the field of view simultaneously as it is, of course, the usual situation in everyday vision. From 3-months of age rapid improvement in the ability to make attentional shifts reflect a changeover from subcortical control to cortical control mechanisms (Farroni et al., 2013).

Disengagement can occur from 3-months as the cortical structures begin to play a role enabling infants to disengage attention from one visual object of interest and foveate a newly appearing target due to the cortical control within the parietal and frontal lobes. These changes are also due to the deep layers of the visual cortex developing before the superficial ones. This developmental sequence may allow certain cortical neuronal circuits to become functional before others and certain eye movement behaviours consequently being present before others (Elsabbagh et al., 2013).

A shift of attention and gaze shifting are tightly associated. The close coupling of VEMs and the underlying neuronal attention networks make orientating to attention

tasks by means of VEMs an ideal means of assessing attentional functional neural development.

In clinical practice, these long sticky fixations without disengaging are quite common, indicating cortical lesions and decreases by improving saccades as part of purposeful goal-directed actions. During treatment, it has been observed that saccade latencies decreased over a trial number, suggesting a learning effect is possible in the non-competition and competition condition.

Two well-established behavioural methods, the Fixation Shift Paradigm (FSP) (Farroni et al., 2013) and the Gap Paradigm (Ross-Sheehy et al., 2017), use shifts of gaze to measure shifts of attention. Both measure saccadic latency from central point to a peripheral visual target that is related to fixation switches. The understanding of how you present visual information to an infant with neurological insults can assist or limit the visual processing systems. Therefore, it is important to know the role of these two paradigms and their neurological processing as it can influence the outcome of the assessment measurement.

## **2.21 PUPILLARY REACTION TO LIGHT**

Evaluation of the pupillary reaction is clinically important in localizing lesions involving the optic efferent and afferent pathways. The pupillary response is an innate reflex (Johnson, 1989). The pathway for the light response is entirely subcortical. The afferent pupillary fibres are included within the optic nerve and visual pathways until they exit the optic tract just prior to the lateral geniculate nucleus. They enter the midbrain through the brachium of the SC and synapse in the pre-tectal nucleus. Each pre-tectal nucleus projects to the ipsilateral and contralateral preganglionic parasympathetic neurons in the Edinger-Westphal nucleus or so called the accessory oculomotor nucleus. The preganglionic neurons in the Edinger-Westphal nucleus send axons out to the brain stem in the oculomotor nerve to innervate the ciliary ganglion. This ganglion contains postganglionic neuron that innervate the smooth muscles of the sphincter muscle of the iris (Lyle, 1990).

The pupillary light response is absent in infants of 29 gestational weeks or less but is usually present by 31 weeks. At birth the pupil is small, and it enlarges in the first

few months of life. Pupillary responses are important clinically as it indicates the functional state of the afferent and efferent pathways (Hoyt, 2007).

The light shone into the right eye produces an immediate direct response in the right pupil and an immediate, indirect consensual response in the left pupil (Kite & Whitley, 2018). If light directed to the left pupil of an infant elicits a consensual response in the right pupil but not a direct one in the left pupil this response means that the afferent limb of the pathway, the optic nerve is intact but the efferent to the left eye is damaged possibly by the oculomotor nerve. In contrast, if the optic nerve is lesioned unilaterally light shone in the affected eye will cause no change in either pupil, but the light shone in the normal eye will elicit both a direct and consensual response. The observer uses a bright light that is shone in each eye for three seconds while the infant, if possible, has his/her fixation maintained at one position, preferably in the distance. Differences in the direct and consensual responses are recorded. The clinician shifts the light from one eye to the other in the swinging flashlight measurement to detect any dilation of the pupil when it is illuminated. If the pupil does dilate, the infant may have poor vision in that eye, and further testing is warranted. The pupil of a totally blind eye usually does not respond to light shone in the eye, but when the light is shifted to the unaffected eye, both pupils constrict. Children with CVI tend to have a latency response (Atkinson & Braddick, 2012).

## **2.22 GENERAL DISCUSSION ON THE CHARACTERISTICS OF A STIMULUS FOR THE VEMMT**

Colour preferences play an important role in directing our attention to the visual environment (Adams & Courage, 1995). Colour is a very salient environmental cue and allows us to recognize, classify, categorize, and remember objects in a very efficient manner (Adams, 1987). Infants at 3-months of age are sensitive to all three primary colours (Atkinson, 2002). Colour vision improves greatly over the first 3-postnatal months, and most typical 3-month-olds showed a preference order of red, yellow, blue and green (Atkinson, 2000).

Visual signals are processed by the rods and by three types of colour photoreceptors, namely the long (L), mid (M) and short (S) wavelength cones (Atkinson, 2002) which have different peak spectral sensitivities. Therefore, colours are the way the brain, by use of eyes, interprets electromagnetic radiation of a

wavelength within the visible spectrum. Visible light lies approximately between 400 and 700 nanometers (nm). Electromagnetic radiation with a wavelength of over 750 nm is called infrared, and radiation under 350 nm is ultra-violet. Each colour on the spectrum can vary in saturation, lightness, or darkness (Adams, 1989). Adams et al. (1997) showed new-born infants discriminate white from several wavelengths red, green, and yellow large chromatic stimuli. They (Adams & Courage, 1995) found in their habituation-recovery paradigm study of 1-3-month-old infants that 1-month olds showed evidence of discriminating red from the green but failed to discriminate either of these from yellow. At 2-months, infants showed evidence of discriminating green from yellow, but at 3-months, infants discriminate red from yellow.

The preferred colour identified in this study is associated with entities important for infants' development and survival. The red coloured light in this study closely corresponded to the chromatic locus of lips attracting the infant's attention to the mouth. The mouth is important for detecting emotional expressions and language learning, even if young infants preferentially fixate the eyes over the mouth. Another entity important for infants' development or survival with the same light reddish colour is the nipple (Taylor et al., 2013).

Colours have associated object valences in infancy as well. Sensory-motor experiences build up a memory of colours associated with objects (Taylor et al., 2013), and the recognition of canonical colour strongly influences the visual perception of objects (Hansen et al., 2006). Infants between 6.5 and 7-months of age can learn the association between a particular colour and specific objects during daily experiences. Kimura et al. (2010) explored the infant's ability to identify the canonical colours of daily objects. They investigated if 5-8-month-old infants can discriminate and recognize colours of daily objects from inappropriately coloured ones. By using a preferential looking technique, they recorded and compared infants' preferences between two 9.8 x 9.8 cm female frontal faces and flowers, side views of fruit, 15 cm apart of the same object: 1 coloured correctly and the other coloured inappropriately. A colourful fixation figure in the centre of the monitor of 6 cm with a short beeping sound attracted the infant's attention. The results revealed that the total looking times for faces were the longest and that the 6-month-olds

preferred the correctly coloured pictures of faces, indicating the emergence of colour constancy.

From the previous paragraphs, it is stated that infants are:

- visually active,
- visually inspect their environment for objects of interest,
- gain volitional control over their eye movements, while their
- gaze shifts become flexible and strategic as they develop.

## **2.23 CONCLUSION**

This chapter outlined how VEMs relates to functional vision. The inclusion criteria further explained the development of visual functions. The accumulating knowledge of typical development allows the OT practicing in early intervention with more certainty when development is not typical.

Voluntary eye movements during communication, social interaction, near task activity, mobility, orientation as well as activities of daily living is part of functional vision. The principle to see to learn, to learn to see is incorporated in this study. Atypical eye movements resulting in visual dysfunction not only put an infant's overall development at risk but compromise future purposeful functional vision.

As clinicians, an infant should be presented with the best possible chance to utilize VEMs efficiently for participation. Measurements are important for early detection and referrals to an optometrist or ophthalmologist where a differential diagnosis can be made to optimize existing visual performances. Early detection leads ultimately to neuroplasticity, a window of opportunity.

The second chapter focused on the relevant published literature fundamental to this study. The content and principles in support and conceptualization of the VEMMT were also discussed in this chapter to present a background to this study.

The relationship between the neuronal network, VEMs, attention and the infant's participation and performances were emphasized. Chapter 2 gave a detailed background knowledge for the identification of test items, measurable indicators in

each domain and sub-domains identified for this study. These measurable indicators and items support functional vision in the ICF framework.

The variability and complexity of typical VEMs in infants 6-to-7-months of age to take part in activities for participation are an astonishingly wide topic. The detailed literature had identified, defined and analysed the construct of the VEMMT in typical 6-to-7-months-old infants.

The following chapter focuses on the methodology in terms of the four objectives and on the research approach and methods. This includes the study design, study population, sampling, data, collection and data analysis.

# **CHAPTER 3**

## **RESEARCH APPROACH AND METHODOLOGY**

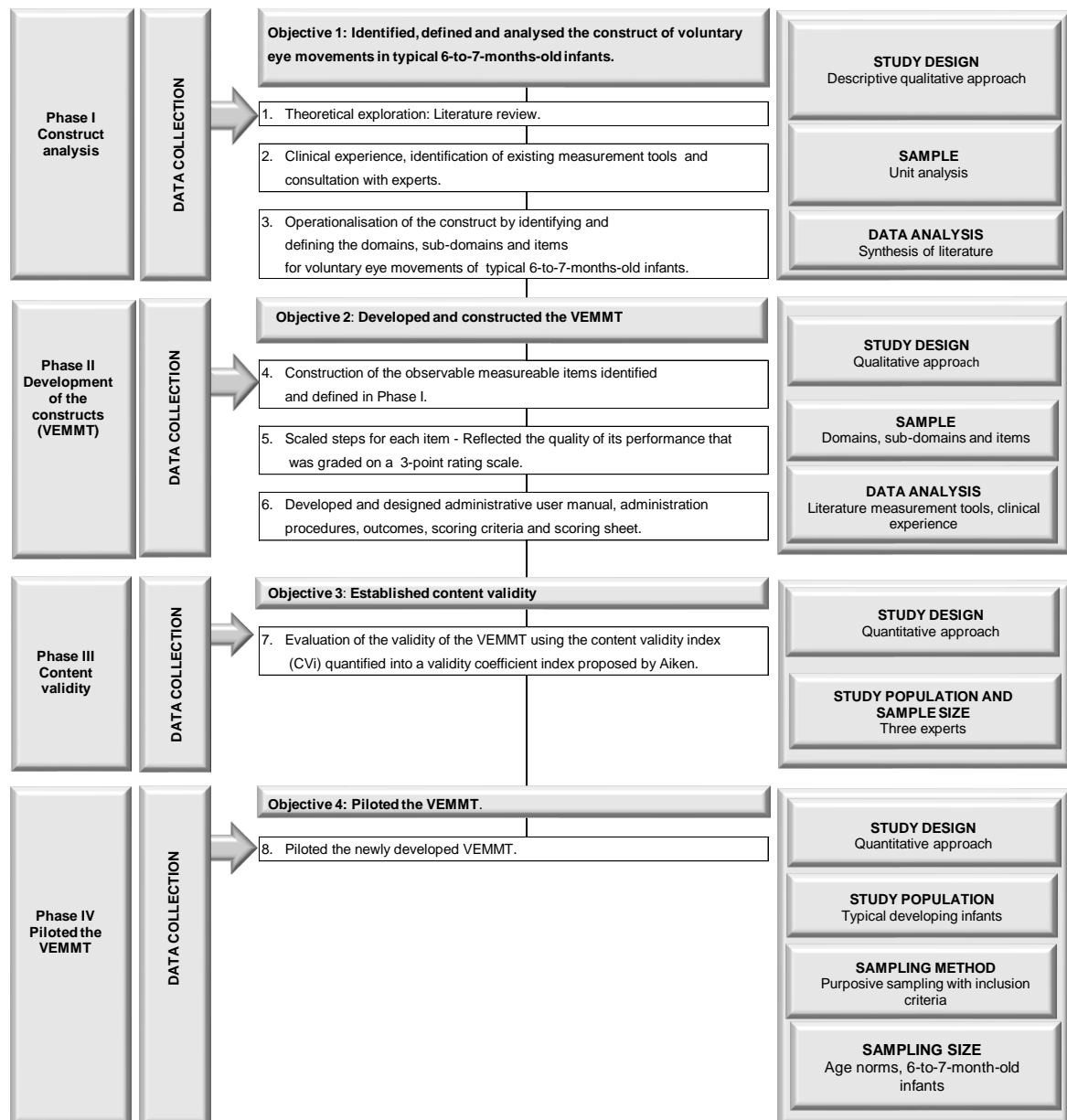
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### **3.1 INTRODUCTION**

This chapter focusses on the methodology utilized to address the four objectives in terms of the research approach, design and methods. The four objectives were aligned with the four distinct phases. Chapter 3 provided more of an overview of the Phases and methodology used in each Phase. The details of the methodology for each phase are presented with the Chapters 4, 5 and 6, which are also focussed on the results/analysis of each Phase. Phase I and II is described in detail with Chapter 4, Phase 3 with Chapter 5 and Phase IV with Chapter 6.

Table 3.1 gives a summarised overview of the four phases used to develop the VEMMT.

Table 3.1: Overview of research methodology



### 3.2 RESEARCH APPROACH AND DESIGN

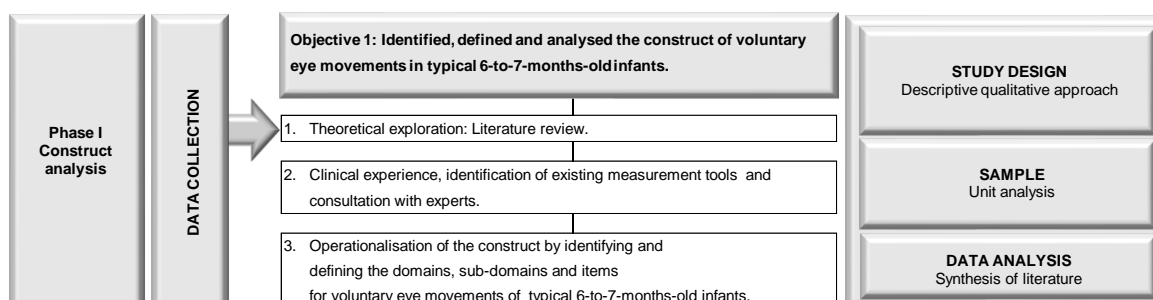
Research methods according to Polit and Beck (2018) are techniques used to structure a study with gathering and analyzing information in a methodical manner. Fundamental research principles and a strong methodological approach are crucial to enhancing the value of any study. Both qualitative and quantitative approaches were followed in the current study with the researcher adopting a model similar to that outlined by Miller et al. (2011) in developing the VEMMT which was achieved in phases. The four phases visualized in Table 3.1. consisted of construct analysis,

development of the construct (VEMMT), to validate content and piloting the VEMMT. Each phase will be discussed separately.

### 3.3 PHASE I: CONSTRUCT ANALYSIS

Phase I focussed on the construct analysis. Table 3.2 represented the steps taken to identify, define and analyse the construct of the VEMMT in typical 6-to-7-months-old infants.

Table 3.2: Research methodology for Phase I: Construct analysis



#### 3.3.1 Objective one

Objective one was to identify, define and analyse the construct of VEMs in 6-to-7-months-old infants by means of a theoretical exploration of literature, reviewing existing voluntary eye movement instruments/tools in children, personal communication with authors/publishers, consultations with experts in the ophthalmology-neurology field and clinical experience. The defined domains, sub-domains and items reflect the 6-to-7-months-old infant’s capability for using VEMs in naturalistic interaction with persons, objects or environment.

#### 3.3.2 Study design

A descriptive, qualitative research design was employed for Phase I. Descriptive research (Mabbott, 2013; Leedy & Ormrod, 2020) provides an accurate portrayal or account of characteristics of a particular individual, which in this study focussed on VEMs in typical 6-to-7-months-old infants. Moreover, Polit and Beck (2018) defined qualitative research as the investigation of phenomena which in this study entailed personal communication with authors/publishers, consultations with experts in the ophthalmology-neurology field and clinical experience of the researcher. A qualitative research design was considered applicable for this phase of the study as

it is a method employed in data collection giving a full description of the research with respect to the participants involved (Patten & Patten, 2018). The participants' observation to create a wider understanding of visual behaviour as described in a qualitative research approach provides data about real life people and situations (Moen & Middelthon, 2015; Leedy & Ormrod, 2020) and is the type of research that finds out about people's experiences. It is concerned with subjective meanings and is thus different from the pursuit of objective facts as in the case of quantitative research.

### **3.3.3 Sample**

The researcher did a critical review of what has already been researched on neuroplasticity and the development in the visual action and perception systems. The unit of analysis was VEMs. Through a literature search the domains, subdomains, and test items were identified, described and analysed.

### **3.3.4 Data collection**

To identify observable items, which would reflect the infant's capabilities for using VEMs in naturalistic interaction with persons, objects or environment, the current theory available in this area were explored by MEDLINE/PubMed/Mendeley/University of Pretoria's data base and catalogue. Books and existing measurement tools with manuals were included. In addition, being part of a multi-disciplinary team, discussion between the researcher and colleagues occurred nationally and internationally. As the researcher is also trained as an ophthalmologist assistant, opportunities arose to communicate in person with ophthalmologists and optometrists. The researcher's clinical experience assisted in the compilation of the operationalisation of the construct VEMMT, related to functional vision by identifying and defining the domains and sub-domains and selected items for VEMMT of a typical 6-to-7-months-old infants. For the purpose of indexing and retrieval the key words used in this research project were voluntary eye movements, neurology of eye movements, developing visual brain, functional vision and visual function.

### 3.3.5 Data analysis

The researcher presented a thorough analysis of the literature by synthesising (cf. 4.1) the neurology of VEMs, typical development of VEMs, functional vision, visual function and the developing visual brain in typically developing 6-to-7-months-old infants (cf. 4.2). The literature study gave an overview of typical development and VEMs development for participation in perceptual and action activities. An in-depth, holistic approach was used to identify, analyse and define the domains, sub-domains and items of VEMs that relate to functional vision for participation in communication, social interaction, near task activities, orientation and mobility. This was considered important to enable clinicians to increase their understanding of essential VEMs domains, sub-domains and items that contribute to overall function and participation, during utilization of the VEMMT (cf. Table 4.2).

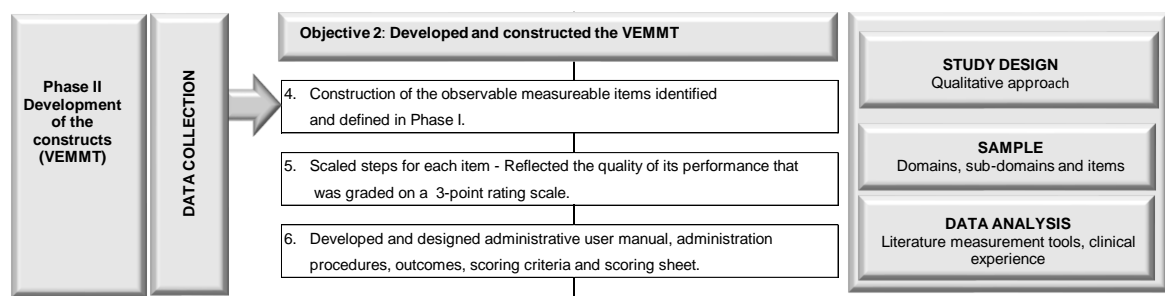
### 3.4 PHASE II: DEVELOPMENT OF THE CONSTRUCT

Phase II focussed on the development of the construct. Table 3.3 represents the steps taken to develop the VEMMT in typical 6-to-7-months-old infants.

#### 3.4.1 Objective two

Objective two was focussed on developing and constructing the VEMMT. The VEMMT was constructed by observing VEMs performed during social interactions, near tasks, mobility and orientation activities with attention (cf. 4.4; 4.5). Table 3.3 provides an overview of the steps taken to achieve this objective.

Table 3.3: Overview of Phase II: Develop and construct the VEMMT



#### 3.4.2 Study design

Qualitative method was utilized in this phase of the study. To gain detailed answers to the research question a qualitative method was used by exploring the different concepts and theories in literature under investigation (Hennink & Hutter, 2020).

### 3.4.3 Sample

The unit of analysis of the VEMMT was domains, sub-domains and items of VEMs in typically developing 6-to-7-months-old infants. The VEMMT was constructed by observing VEMs performed during social interactions, near-task, mobility and orientation activities with attention.

### 3.4.4 Data collection

The development process of Miller et al. (2011) was used for the planning of the content to be measured, the format and very specific instructions for administering and scoring (cf. Table 4.3; 4.4 & 4.7).

### 3.4.5 Data Analysis

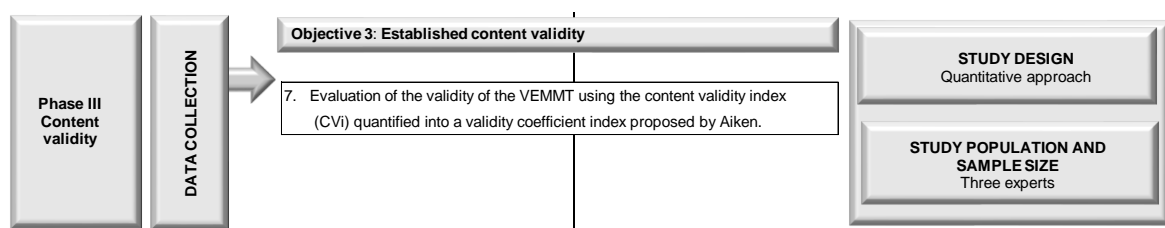
The content of the observable measurement items served as a basis for data analysis and was accomplished by the establishment of content validity (cf. 4.5).

## 3.5 PHASE III: ESTABLISH CONTENT VALIDITY

### 3.5.1 Objective three

Content validity refers to the degree that the instrument covers the content that it is supposed to measure (Fitzpatrick, 1983) and is one of the most critical steps in instrument development (Berg-weger, 2003). Table 3.4 represents the steps taken to establish content validity of the VEMMT.

Table 3.4: Steps to establish content validity



Content validity is concerned with the representativeness or sampling of the content of an instrument (Delport & Roestenburg, 2011). A valid measure would provide an adequate or representative sample of all content or elements, or instances of the phenomenon being measured. As the VEMMT was designed to measure an infant's VEMs that supports or interferes with functional performance and development, it should be psychometrically sound.

### **3.5.2 Study design**

To establish content validity of the VEMMT a quantitative research designs was followed. A quantitative research design is appropriate for assessing content validity (Hennink & Hutter, 2020).

### **3.5.3 Study population and sample size**

The study sample for this objective was obtained from 3 experts in the paediatric field of ophthalmology (Neurology), optometry and occupational therapy and included individuals who were currently practising and/or lecturing; and/or with research skills. As the study population was small number, the sample was selected purposively (non-probability). Hennink and Hutter (2020) confirmed that a small study population is acceptable to establish content validity. Lynn (1986) suggested that three experts are the minimum number for the establishment of content validity.

### **3.5.4 Data collection**

In order to establish content validity index (CVi):

- Personalized email invitations were sent to the experts outlining the purpose of the study and to request their participation (Appendix E).
- Upon receipt of confirmation of their availability to serve on the expert panel, a cover letter of the study and content validity questionnaire (Appendix J) was emailed to them.
- All detailed instructions on the newly developed VEMMT were provided to each of the expert panel members.

### **3.5.5 Content validity index**

The CVi consisted of items that rated the content by the expert panellist on a 4-point scale. The expert panellist rated the VEMMT by using the CVi to scale the:

- VEMMT relevance/ purpose based on the defined and selected observable measurable items for VEMs in infants 6-to-7-months-old infants,
- identifiable measurable criteria for VEMMT, and
- guidelines for procedures including the layout and ease of use for a clinical setting.

### **3.5.6 Aiken content indices**

In this study, the statistical method of content validity coefficient proposed by Aiken was adopted (Penfield, 2009). The degree of agreement among the participants regarding the importance of the item content was quantified into one coefficient (V value) to determine the level of relevance (Aiken, 1980).

### **3.5.7 Data analysis**

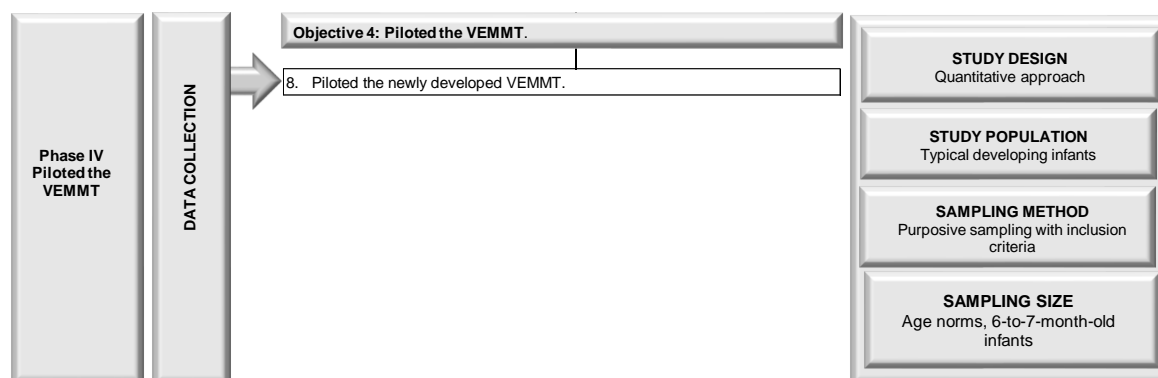
Feedback from the participants was reviewed for identifying areas of omission and suggested areas of item improvement or modification. Ambiguous and unclear items were rephrased, or minor alterations were made as the required coefficient was set at  $V = 0.80$  (Lynn, 1986).

## **3.6 PHASE IV: PILOTING THE VEMMT**

### **3.6.1 Objective four**

The fourth objective was the testing of the newly developed VEMMT. The aim of the pilot study was to ensure that the test scores were accurate and meaningful (Miller et al., 2011). This phase assessed if the administrative user manual, administration and scoring, and scoring sheet were user friendly in order to identify potential problems that needed correction. It provided an examination of how the VEMMT worked and the results that it yields. It revealed its purpose and its suitability for both the examiner and the infants. Table 3.5 represents the steps taken to test the newly developed VEMMT.

Table 3.5: Steps taken to pilot the newly developed VEMMT



### 3.6.2 Study design

Qualitative and quantitative design. The qualitative part entailed the descriptive and conceptual findings from literature search and personal interviews with experts in the field of paediatrics, ophthalmology and neurology.

### 3.6.3 Study population

Typical developing infants between 6-months day 1 up to 6-months day 30/31 (6-to-7-months) formed the sample for this phase of the study.

### 3.6.4 Sampling method

Although the researcher received permission letters from Department of health in North West Province to conduct the pilot at the clinics in the district, it was no longer possible due to the COVID-19 pandemic (cf. 6.4). The researcher identified infants who met the inclusion criteria by using a purposive sampling. The researcher was tested for covid 72 hours prior to the assessment and tested a typical infant in the presence of the PCG who was also tested negative in the same period at the researcher’s clinical private practice. This continued on the basis of availability and the health situation until a minimum sample of eight subjects was obtained.

### 3.6.5 Sample size

The sample was reduced due to the COVID-19 pandemic. The research ethics committee granted an ethical certificate on request by the researcher to reduce the number of study subjects and the sampling method. The total number of infants who formed the sample was eight.

### **3.6.6 Inclusion criteria**

To ensure compliance with the inclusion criteria, the infants 6-to-7-months-old underwent an examination performed by the researcher based on typical development in VA, CS, VF and perceptual-motor-social development (Ages and Stages Questionnaire, ASQ-3) and were scored (Appendix I). An overview of the inclusion criteria is presented in Table 3.6. The infants who met the inclusion criteria, participated in the VEMMT. The typical parameters used as an inclusion criterion for VA, CS, VF and ASQ-3 are documented in Table 3.7. If participants did not meet the criteria, they were excluded from this research study and intervention activities with a follow-up session at the practice of the researcher was provided. The choice of language (English, Tswana and Afrikaans) of the parents was used during the VEMMT sessions. An interpreter assisted with Tswana if necessary.

Table 3.6: Overview of the inclusion criteria

Key features	Inclusion criteria			
<b>Covid testing</b>	Both the researcher and PCG show negative test 72-hours prior the appointment.			
<b>Alert state of the infant</b>	The infant should be rested and fed. An alert state 4 is defined as alert with a bright look and focus is on visual or auditory stimuli with minimum movements.			
<b>Biographical information</b>	Age range: 6-months 1 day – 6-months 30/31 days.	Infants from 37 weeks to full term gestation.	Normal birth weight (2,500 grams or above).	No diagnosed disability.
<b>Visual functions</b>	<b>VA</b>	<b>CS</b>	<b>VF</b>	
Methods	Teller acuity grating cards	Hiding Heidi contrast cards	Confrontation method (Kinetic field testing).	
Authors	(Dubowitz, 1979) (Teller et al., 1986).	(Beazley et al., 1980).	(Lewis & Maurer, 1992).	
	Preferential looking paradigm			
Definitions	Visual acuity is the ability to resolve or recognise fine details and the value usually refers to the size of the smallest optotypes that the child could recognise on the acuity cards.	Contrast sensitivity measures the ability to see differences in the amount of light reflected from adjacent surfaces. This ability allows a person to notice edges and shadows that define objects and also shows the depth and placement in space.	The visual field is the extent in space in which objects are visible to a stationary eye.	
<b>ASQ-3</b> To identify any developmental delays	<b>Family</b> • Baby's information • Details of PCG	<b>Items scored</b> • <b>Communication:</b> Babbling, vocalizing, listening and understanding. • <b>Gross Motor:</b> Focuses on arm, body and leg movements. • <b>Fine Motor:</b> Pertains to hand and finger movements. • <b>Problem-solving:</b> Addresses learning and playing with toys. • <b>Personal-social:</b> Focuses on solitary social play and play with toys and other children.	<b>Information</b> Infant's who did not score developmentally appropriate were excluded.	<b>Parental concerns</b> The information from the overall section of the questionnaire served as a general indicator of parental concerns. Infants were excluded if there were parental concerns.

Table 3.7: The typical parameters for VA, CS, VF and ASQ-3

Parameters	Norms for inclusion criteria in 6-to-7-month-old infants.	Distance	Scoring criteria for inclusion																																																																																																
<b>VA (Teller acuity cards).</b>	The expected binocular acuity norms: 1.3, 2.4 and 4.8 CY/CM. (Teller, McDonald, Preston, Sebris & Dobson, 1986).	55 cm	Need all three responses for inclusion <table border="1"> <thead> <tr> <th>CY/CM</th> <th>Response</th> </tr> </thead> <tbody> <tr> <td>1.3</td> <td></td> </tr> <tr> <td>2.4</td> <td></td> </tr> <tr> <td>4.8</td> <td></td> </tr> </tbody> </table>	CY/CM	Response	1.3		2.4		4.8																																																																																									
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White area	A score above the cut-off	Indicated that the infant appears doing well in that developmental area and will be included in this research project.																																																																																																	
Light purple	A score close to the cut-off	Means that the infant may need practice in that area and will be excluded from this research project.																																																																																																	

### **3.6.7 The value of the inclusion criteria measurements instruments**

The process of clinical reasoning was undertaken for the identification of relevant items that could be adapted from the inclusion measurement instruments for the development of the VEMMT. Table 3.8 summarises the more important relevant items.

Table 3.8: Relevant items identified for the development of the VEMMT

<b>Behavioural method</b>	The preferential looking paradigm was used in this research project, by applying the principle of:” There is something or nothing” and/or the eye will move if the brain can “see” it. Use different toys to attract the infant’s attention.	
<b>The use of stimulus cards</b>	Reduce clutter in the environment. The stimulus cards were vertical to prevent lower or higher luminance.	
<b>Visual Acuity</b>	<b>Environment</b>	Illumination: Diffuse fluorescent lights in the clinical setting is adequate. Natural light assists.
	<b>Test distance</b>	Any distance between 38-55 cm for recognition and detection.
	<b>Positioning</b>	Infant in a supportive sitting on parent’s lap Adjustable height chairs for aligning the infant’s eyes with the examiner’s eyes. The examiner should look at the person holding the infant during the administration.
	<b>Attention</b>	Tap on back of card to attract attention. Use different toys
<b>Contrast sensitivity test</b>		Recognition and expression of faces Face pictures have attraction. Response: Combined movement of eyes and head.
<b>Visual field</b>	Methods	Confrontation methods give useful information.
	Range of VF	The examiner in front observes the infant’s eye movements to determine how close or how far the peripheral target can be in the visual field before the infants detects it. In this way, both the size of the infant’s visual field can be determined.
	Response	An infant with full visual fields will make a rapid head turn or eye movement towards the peripheral target.
<b>ASQ-3</b>	Toys	Size of toys that can be used as small as a cheerio and block of 4 cm x 4 cm.
	Interpreter	Used the guidelines as recommended.

### **3.6.8 Data collection**

Invitational letters were sent to paediatricians, general practitioners and clinics and were asked to assist with the distribution of invitational letters to PCG with typical infants 6-to-7-months-old infants. Typical is defined as infants between the age range 6-to-7-months, full term gestation, normal birth weight (2,500 grams or above) and without any diagnosed disability (**cf.** Appendix B). The data was determined through the implementation of the inclusion criteria followed by the administration of the VEMMT. The inclusion criteria scoring and administration of the VEMMT were administered in one setting. The VEMMT administration process was video recorded to assist with the scoring of the items. The researcher combined the administration by direct observation of the VEMMT administration procedures to facilitate accurate item assessments. The identity of the infant was protected by assigning a code/number to the infant. The video recordings will be kept safe on a password protected computer and after submission of the thesis, it will be in safe keeping at the University of Pretoria for 15 years.

## **3.7 ETHICAL CONSIDERATIONS**

### **3.7.1 Ethical Approval**

Ethical approval was obtained from the Ethics Committee of the Faculty of Health Sciences, University of Pretoria. The allocated Ethics Committee approval number of the Faculty of Health Sciences is ECUP no. 216/2020.

### **3.7.2 Informed consent**

The researcher received written, informed consent (Appendix C) or verbal informed consent (Appendix D) from the PCG over the age of 18 years, who took part in the study. The informed consent form was accompanied by an information letter (Appendix B) about the study in English, Afrikaans or Tswana according to their preference. The information letter was based on the guidelines for informed consent as described by the general guidelines of the Ethics Committee of the Faculty of Health Sciences. The provision of informed consent as asserted by Muller and Schaber (2018) implied that the parents had sufficient information about the nature of the study and objectives for them to decide whether to participate or not. Parents were informed that their participation was voluntary and that they had the right to withdraw at any time without prejudice.

### **3.7.3 Interpreter for the Ages and Stages Questionnaire-3**

Even if a family is using a translated questionnaire, they may still need an interpreter to help them understand the instructions, communicate questions to the researcher or to help them discuss their infant's results in a meaningful way.

The interpreter was guided and informed by the researcher on the meaning of terminology and procedures by means of preliminary discussions. A triangle format of positioning was used, with the researcher and family member across from each other and the interpreter seated to the side.

After the questionnaire was completed, responses were provided by the researcher to any of the family's concerns or questions. Through the interpreter a summary was given immediately.

### **3.7.4 Respect and protection**

The researcher respected the autonomy and protected the welfare of all participants and assured that all personal information will be kept private and will not be disclosed without informed consent. Infants represent a vulnerable group of research participants. By enrolling infants into this research, permission had to be obtained from the PCG who then also became participants in this research and were informed that none of the procedures presented any risk of injury to the infant (Diekema, 2009). The infants' identity was kept confidential, and each infant received a code, which was used in the written document. Video recordings of the infants' VEMs were made. The PCGs were asked to sign consent before the video recordings were made. Video recordings were not used outside the parameters of the research study. Any hard and electronic copies will be shredded and deleted, respectively. The researcher respected the right of individuals to refuse to participate in research and to withdraw their participation at any stages. No payments or incentives were offered to PCG for research participation.

### **3.7.5 The principles of accountability**

Parents/caregivers/guardians was offered the opportunity to ask questions and the researcher answered the questions willingly. Explanation of results were given in an emphatical manner. Two infants failed the inclusion criteria and received a program

to assist with their development. Culture or language issues was taken into consideration.

### **3.8 CONCLUSION**

This chapter gave an overview of the methodology that was applied in this study. Methods for the four objectives were discussed to provide background to the study. The four objectives were aligned with the four distinct phases. Phase I and II will be discussed in the following chapter.

# **CHAPTER 4**

## **THE VOLUNTARY EYE MOVEMENT MEASUREMENT TOOL**

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### **4.1 INTRODUCTION**

This chapter focuses on the development of the VEMMT. The VEMMT is developed in typically developing 6-to-7-months-old infants for the identification of atypical eye movements that restrict participation with activity limitations in near task activities, social interactions, mobility and orientation. Consideration of the nature of the sensory-motor processing which would seem to be needed for development, led the researcher to believe that infants need specific abilities and skills in the dynamic systems for purposeful directed actions and perception (Von Hofsten, 2004; Russel et al., 2018).

The literature review that was the cornerstone for the developmental phase in this research study, emphasised the importance of VEMs as a prerequisite of functional vision in the developing infant. The domains, sub-domains and items were identified, defined and analysed.

### **4.2 BACKGROUND TO THE DEVELOPMENT OF THE VOLUNTARY EYE MOVEMENT MEASUREMENT TOOL**

Unidentified sensory visual processing anomalies from an early age can result in lasting developmental changes and losses in interaction with the environment which impacts multiple areas of development (Scheiman, 2011) with a subsequent impact on families or society (Ryckman et al., 2017).

This research followed on from a quantitative, descriptive, correlations study done by the researcher for a Master's degree (Scholtz et al., 2013). The results showed that children between the ages of two and ten years, diagnosed with CP might have deficits in postural alignment that affect eye movements. It was concluded that early identification of atypical VEMs is thus of utmost importance in infancy for the maintenance and full development of innate mechanisms that endow the visual system and its highly specific connections.

An infant's functioning system, specifically VEMs, is fully developed by as early as 6-months of age, before other functions such as the ability to walk and talk. This points to functional vision being the necessary precursor to the proper development of other bodily and mental functions for goal-directed activities and participation related to social abilities (Dusing, 2016). At 6-months marked developmental milestones have been reached and the infant has positional stability with symmetry (Bly, 2014). A 6-month-old infant can sit independently without external support, free the arms to reach with the arms and grasp, hold, release toys while sitting (Alexander et al., 1993). Voluntary eye movements are fully developed in 6-months-old infants with peripheral visual field responses within 180 degrees indicating that the age range 6-to-7-months is an appropriate age group to identify deviations from typical development (Erhardt, 1990). The age group of 6-to-7-months was chosen to increase additional days of age and also anything less than 6-months of age would have been inappropriate due to the immaturity of the neural development.

The VEMMT is a unique integrated functional vision measurement for infants 6-to-7-months. The evidence from published literature, personal communication with experts, existing measurement tools and the researcher's personal experience working with infants with neurological dysfunction and their PCG, reinforced the scientific reasoning. A new VEMMT was developed. The development of the VEMMT was conducted in four phases and Table 4.1 gives a summarised overview of the four phases. The four phases will be discussed in different sections. This chapter focusses on Phase I and II of the development of the VEMMT.

Table 4.1: Overview of the four phases in the development of the VEMMT

<b>Phase</b>	<b>Description</b>	<b>Steps taken for the establishment of objectives.</b>
Phase I	Construct analysis	<p>Theoretical exploration: Literature review.</p> <p>Clinical experience, identification of existing measurement tools and consultation with experts.</p> <p>Operationalisation of the construct by identifying and defining the domains, sub-domains and items for VEMs of typical 6-to-7-months-old infants.</p>
Phase II	Development of the VEMMT	<p>Construction of the observable measurable items identified and defined in Phase I.</p> <p>Scale steps for each item - reflecting the quality of its performance that was graded on a 3-point rating scale.</p> <p>Developed and designed administrative user manual, administration procedures, outcomes, scoring criteria and scoring sheet.</p>
Phase III	Content validity	Evaluation of the validity of the VEMMT using the CVi quantified into a validity coefficient index proposed by Aiken.
Phase IV	Piloting the VEMMT	Pilot the new developed VEMMT.

# PHASE I

## CONSTRUCT ANALYSIS

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### 4.3 DOMAINS, SUB-DOMAINS AND ITEMS

Infants depend upon clear vision for obtaining detailed information about the visual world, as well as where it happens in the central and/or peripheral field of vision (Leat et al., 2009). Different VEMs can be distinguished on the basis of how they aid vision, their physical properties and their anatomical substrates (Richards & Holley, 1999). These VEMs were observed and systematically examined. Operationalisation of the construct involved identifying and defining the domains, sub-domains and selected observable items for VEMMT of a typical 6-to-7-months-old infant.

The ICF-CY has been used as a reference for the development of the VEMMT. Participation (domains), activities, (sub-domains) and items (body function and structures) are related to the functions of multiple other single VEM systems (Simeonsson, 2009). The purpose of the VEMMT is to measure and describe how efficiently infants use VEMs during participation. Table 4.2 summarises the identified and defined domains, sub-domains and items.

Table 4.2: Identified and defined domains, sub-domains and items

<b>DOMAIN A: FUNCTIONAL VISION FOR PARTICIPATION</b>		
<b>SUB-DOMAIN 1: NEAR TASK WORK</b>		
<b>ITEM</b>	<b>DESCRIPTION</b>	<b>DEFINITION</b>
1	Look, reach, grasp, hold and release rattle with the right hand.	Looking, reaching for, grasping, holding and releasing an object placed at 30 degrees is registered as one-handed to the right.
2	Look, reach, grasp, hold and release rattle with the left hand.	Looking, reaching for, grasping, holding and releasing an object placed at 30 degrees is registered as one-handed to the left.
3	Looking, reaching, touching and holding a ball, with both hands to midline.	A two-handed reach is defined as both hands approaching the object simultaneously, to actively hold the presented ball.
4	Adaptive reach with tactile input.	Adaptive motor skills response is the ability to plan and act on an object with a tactile input in an organised way.
<b>SUB-DOMAIN 2: SOCIAL INTERACTION</b>		
<b>ITEM</b>	<b>DESCRIPTION</b>	<b>DEFINITION</b>
5	Peek a Boo.	Social brain activation is by reading social interaction cues during direct gaze (holding) and shifts (gaze shifting).
6	Gaze following.	Gaze following is the ability to look where somebody else is looking and is a fundamental element of face-to-face interaction, a precursor to language development and part of inter-relationships between perceptual-cognitive and social development.
<b>DOMAIN B: GAZE HOLDING</b>		
<b>ITEM</b>	<b>DESCRIPTION</b>	<b>DEFINITION</b>
7	Muscle balance in different directions.	Alignment acts as a platform for binocular sensory development. Binocular alignment is when the image of the object of regard falls simultaneously on the fovea of each eye, and the vertical retinal meridians are both upright due to coordinated extra-ocular muscles.
8	Direct penlight reflection.	Alignment acts as a platform for binocular sensory development. Binocular alignment is when the image of the object of regard falls simultaneously on the fovea of each eye, and the vertical retinal meridians are both upright.
9	Ocular alignment cover/uncover.	Alignment acts as a platform for binocular sensory development. Binocular alignment is when the image of the object of regard falls simultaneously on the fovea of each eye, and the vertical retinal meridians are both upright.
10	Convergence.	Convergence is the process of using extra ocular muscles to direct the visual axis of the two eyes to a near point, a simultaneous process turning of the eyes inward.
<b>DOMAIN C: GAZE SHIFTING</b>		
<b>SUB-DOMAIN 3: SMOOTH PURSUIT EYE MOVEMENT (SPEM)</b>		
<b>ITEM</b>	<b>DESCRIPTION</b>	<b>DEFINITION</b>
11	Horizontal SPEM.	Smooth pursuit eye movements refer to smooth tracking movements by the eyes alone allowing the eyes to maintain foveal alignment with a horizontal moving target that is voluntarily selected against a stationary background.
12	Vertical SPEM.	Smooth pursuit eye movements refer to smooth tracking movements by the eyes alone allowing the eyes to maintain foveal alignment with a vertical moving target that is voluntarily selected against a stationary background.
13	Circular clockwise SPEM.	Smooth pursuit eye movements refer to smooth tracking movements by the eyes alone allowing the eyes to maintain foveal alignment with a circular clockwise moving target that is voluntarily selected against a stationary background.

14	Circular anti-clockwise SPEM.	Smooth pursuit eye movements refer to smooth tracking movements by the eyes alone allowing the eyes to maintain foveal alignment with a circular anti-clockwise moving target that is voluntarily selected against a stationary background.
<b>SUB-DOMAIN 4: GAZE PURSUIT (GP)</b>		
<b>ITEM</b>	<b>DESCRIPTION</b>	<b>DEFINITION</b>
15	Gaze pursuit from infant's left to right.	Gaze pursuit is when an infant visually tracks a smoothly moving target using a combination of eye and head movements to stabilize the retinal image of a moving target against a stationary background.
16	Gaze pursuit from infants' right to left.	Gaze pursuit is when an infant visually tracks a smoothly moving target using a combination of eye and head movements to stabilize the retinal image of a moving target against a stationary background.
<b>SUB-DOMAIN 5: SACCADES</b>		
<b>ITEM</b>	<b>DESCRIPTION</b>	<b>DEFINITION</b>
17	Fixation shift paradigm.	Fixation shift paradigm occurs under competition conditions. Switching attention under competition involves disengaging from the current stimulus, followed by a shift of attention, monitored as a saccadic gaze shift eye movement to the new target.
18	Gap shift paradigm.	The gap shift paradigm demonstrates the interaction between covert attentional processes and saccadic control. The reaction time to make a saccade to a peripheral target is significantly faster when a central fixation point goes off, shortly before another target is presented (gap).
19	Express saccades.	Express saccades occur from central into peripheral visual field to foveate an object of interest.
20	Pupillary response.	A light shone into an eye produces an immediate pupil constriction in that eye and an indirect pupil constriction in the other eye, so called a consensual response. The pupillary response, an innate reflex, is clinically important in localizing lesions involving the optic efferent and afferent pathways.
21	Exogenous saccades/ blink response.	Exogenous saccades are made to novel stimuli (visual, auditory, or tactile) that unexpectedly occur within the visual environment. Exogenous orienting usually involves salient objects that appear suddenly in the visual field and capture attention with gaze shifting.
<b>DOMAIN D: ATTENTION</b>		
<b>ITEM</b>	<b>DESCRIPTION</b>	<b>DEFINITION</b>
22	Disengagement.	Disengagement assists the infant to shift attention to something new. An infant will turn away from the stimulus in a consistent manner for e.g., look down when finishing with the attention holding.
23	Attention holding.	Attention holding is the maintenance of a stimulus which is intricate or novel. It is reflected by how long the infant engages in cognitive activity involving a stimulus.
24	Attention getting.	Attention getting is considered the initial orientation or alerting to a stimulus and can be observed in head-turning or a gaze shift toward a large, bright object presented in the periphery and/or in the central visual field.
25	Joint attention.	Joint attention refers to the infant's ability to follow the direction of the gaze or gesture of others to share a common point of reference.
26	Sustained attention and self-regulation.	Sustained attention and self-regulation lie in the infant's capacity to direct and focus cognitive activity on specific stimuli while simultaneously regulating arousal and responses to sensory stimulation.

# PHASE II

## DEVELOPMENT OF THE CONSTRUCT (VEMMT)

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### 4.4 VEMMT ADMINISTRATION USER MANUAL

The development of eye-tracking systems has provided a tool capable of evaluating VEMS (Majaranta & Bulling, 2014), however they remain expensive, do not measure the functional outcome of eye movements in early life, and are currently not a practical option for the clinical assessment of functional VEMs in infants 6-to-7-months of age. Moreover, currently there exists no common format to assess functional eye movements in infants 6-months of age which limits the interpretation of the visual behaviour in this age group. The unavailability of a clinical measurable tool to detect VEMs anomalies in the young infant is thus a huge shortcoming. Furthermore, given the importance of the role of VEMs in interaction with the visual environment, this field is of particular interest to OTs working in the field of neurodevelopmental therapy (Stolk et al., 2009; Scholtz, 2013).

The VEMMT is conducted by observing objects and non-object-related actions performed during interactions in a play manner with toys from the VEMMT kit. The sessions are semi-structured and is conducted for about 20 min and is video recorded. The intent is to reflect how typically developing 6-to-7-months-old infants usually interact during mobility, orientation, social interaction and near task work.

Voluntary eye movements can be best understood by considering its function. In this current research study, gaze shifting and gaze holding are identified as the main domains. Attention has emerged as an important aspect throughout all the domains and sub-domains, and it is integrated into all aspects of functional vision (Posner et al., 2014). In Chapter 2 the preferential looking paradigm has been discussed (Pitkow et al., 2007). The preferential looking paradigm is useful to use in infants to measure preferences for objects, contrast, faces and attractive toys. The main advantage of using the preferential looking paradigm in the clinical practice, reaction to gaze holding, and shifting are that they can be calculated and that it does not

require infants to verbalise their symptoms as they also do not follow instructions. The detailed development of the former and latter has been discussed in Chapter 2. From the literature review the user's manual was developed with detailed descriptions on how to administer the VEMMT. The information focused on the background information of the administrative user manual. Table 4.3 represents the index of the content of the user's administrative user manual (Appendix F).

Table 4.3: User's manual index

<b>INDEX</b>	
1.	Overview
2.	User qualifications
3.	Suggested administration procedures 3.1. Computing the infant's chronological age 3.2. Premature infant's corrected age calculation
4.	Guidelines for administrator/examiner 4.1. The Parent/Caregiver/Guardian (PCG) participation
5.	Environment
6.	Infant positioning
7.	Regulatory state of infant
8.	Ocular conditions
9.	Head movement
10.	Dominance
11.	Prompts given during administration
12.	Breaks and termination
13.	Distractors
14.	Test distance
15.	Rating scale
16.	Scoring
17.	Baseline
18.	Timeline and test items
19.	Domains, sub-domains and items A. Eye movements related to functional vision B. Gaze holding C. Gaze shifting D. Attention
20.	The VEMMT kit
21.	Recording the VEMMT
22.	Placement and measurement
23.	Stimulus cards
24.	Description of toys and measurement cards
25.	Preferential looking: warm-up

#### **4.5 ADMINISTRATION AND SCORING CRITERIA**

The VEMMT is developed as a clinical measurement tool for measuring VEMs. Twenty-six items have been identified, defined and analysed for the constructing of the VEMMT. The researcher's interest and clinical expertise in VEMs are not laboratory-based methods but rather from a practical field of knowledge. A laboratory-based method of assessing eye movement is not function orientated. Functional VEMs have specific purposes involving collaborative interactions between the child, their partner and the environment (Leigh & Zee, 2000). Therefore, the importance of this research is not to assess only VEMs per se but also rather measure VEMs during purposeful goal-oriented activities such as reaching for a toy or during social interaction games (Colenbrander, 2003). The VEMMT is to measure VEMs and to describe how efficiently typically developing 6-to-7-months infants perceive visual inputs that they constantly receive from the environment in order to enhance participation and performances for development in all aspects of life. The VEMMT is based on observations of actions performed in an activity that is relevant for this age group (Von Hofsten, 2004). Twenty-one items described different VEMs and were scored on a 3-point scale rating the performance. Items 22-26 are observable behaviours for attention and administered with the video recording. The domains and items to be measured are described in Table 4.4. The toys, measurements, placements and procedures should be presented as indicated in the administration manual and Table 4.5 describes and illustrates item 1: Look, reach, grasp, hold and release rattle with the right hand. The 21 items to be measured followed the same sequence as in Table 4.5 (Appendix G).

Table 4.4: Domains, items, distance, visual field and targets for VEMMT

DOMAINS AND ITEMS					
	Items	Distance	Field	Target	
<b>A. Functional vision for participation</b>	1. Look, reach, grasp, hold and release rattle with the right hand	12 cm	PVF	Rattle 12 cm	
	2. Look, reach, grasp, hold and release rattle with the left hand	12 cm	PVF	Rattle 12 cm	
	3. Looking, reaching, touching and holding a ball, with both hands to midline	12 cm	CVF	Yellow ball 13 cm diameter	
	4. Adaptive reach with tactile input	Infant's hand	CVF	6.5 cm masking tape with red dot, 1,5 cm in middle	
<b>Social interaction</b>	5. Peek a Boo	60 cm	CVF	Examiner's hand and face	
	6. Gaze following	35 cm	PVF	Attractive cars H12 cm, L14 cm, W10 cm	
<b>B. Gaze holding</b>	7. Muscle balance in different directions	40 cm	CVF	Faces 4,5 cm diameter	
	8. Direct penlight reflection	30 cm	CVF	Penlight	
	9. Ocular alignment cover/uncover	30 cm	CVF	Penlight	
	10. Convergence	40 cm	CVF	Puppet 6 cm in diameter	
<b>C. Gaze shift</b>	11. Horizontal SPEM	40 cm	CVF	Puppet 8 cm	
	<b>Smooth pursuit eye movement (SPEM)</b>	12. Vertical SPEM	40 cm	CVF	Puppet 8 cm
		13. Circular clockwise SPEM	40 cm	CVF	Puppet 8 cm
		14. Circular anti-clockwise SPEM	40 cm	CVF	Puppet 8 cm
<b>Gaze shift</b>	15. Gaze pursuit from infant's left to right	40 cm	PVF	Puppet 12 cm	
<b>Gaze pursuit (GP)</b>	16. Gaze pursuit from infants' right to left	40 cm	PVF	Puppet 12 cm	
<b>Gaze shift</b> <b>Saccades</b>	17. Fixation shift paradigm	40 cm	CVF	Cards with stripes, 13 cm x 13 cm with a red dot, 3 cm in middle	
	18. Gap shift paradigm	40 cm	CVF	Light and target 3 cm	
	19. Express saccades	40 cm	CVF	Light different colour caps	
	20. Pupillary response	8 cm	CVF	Light	
	21. Exogenous saccades/ blink response	40 cm	CVF	Examiner's hand	
<b>D. Attention</b>	22. Disengagement				
	23. Attention holding				
	24. Attention getting				
	25. Joint attention				
	26. Sustained attention and self-regulation				

CVF: Central visual field (OU= 30 degrees)

PVF: Peripheral visual field (OU= beyond 30 degrees)

OU: Both eyes

VP: Verbal prompt

NVP: Non-verbal prompt


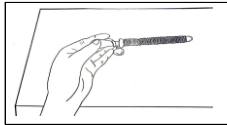

S: Start

C: Center

E: End

Table 4.5: Item 1: Look, reach, grasp, hold and release rattle with the right hand

Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>1. LOOK, REACH, GRASP, HOLD AND RELEASE RATTLE WITH THE INFANT'S RIGHT HAND</b>	
Looking, reaching for, grasping, holding and releasing an object placed at 30° is registered as one-handed to the left and to the right	
<b>EQUIPMENT</b>	<p><b>Toy</b> Rattle, 12 cm in length. <b>Distractor</b> Colourful pom-pom. <b>Positioning</b> The height of table needs to be at the centre of the infant's trunk to free arms.</p> 
<b>PROCEDURE</b>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p>Hide the rattle under the table. Examiner holds it horizontally in her/his left hand. Keep the right hand under the table with a distractor.</p> <p style="text-align: center;"><b>Examiner is not allowed to look at the rattle, keep eye contact with the infant.</b></p> <p>Present the rattle horizontally from the infant's right midline and use non-verbal prompt. Use the marker on the mat for placement of the rattle and use verbal prompt. (The examiner's hand rest on table).</p> 
<b>PROMPT</b>	<p><b>Non-verbal Prompt</b> Wiggle the rattle to make a sound.</p> <p><b>Verbal prompt</b> " Peter, (voice calling first), look, you can take it"</p>
<b>REACH, GRASP, HOLD AND REALESE</b>	<p>Allow time for infant to play. Present a distractor with your right hand, to release attention from rattle, to remove rattle after 10 s.</p> 
<b>OUTCOME CRITERIA</b>	<p><b>Look</b> Head turn and eye movement directly and immediately to the toy on the right. <b>Reach</b> Initiates and reaches easily, smoothly, directed to the rattle with the right hand matches the orientation of rattle: palm facing down. <b>Grasp</b> Right hand is open on approach and grasps rattle with a palmar grasp. <b>Holds</b> Holds rattle and shows an attempt to play for 10secs. Shakes it, plays unilateral or with both hands. <b>Release</b> Transfers toy from one hand to another, taking to mouth to assist with transfer or drops it.</p>
<b>ATTEMPTS</b>	<p>If rattle drops in the 10 s period it can be presented again with the same procedures. Stopped after the second attempt. After 10 s present the visual distractor to remove the rattle.</p>
<b>BREAK</b>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

### 4.5.1 Scoring criterion

The scoring represents the quality of performances. Table 4.6 illustrates the score with a description of the quality of performance.

Table 4.6: Rating scale for quality of performance

Rating Scale	
Score	Quality of performance
2	<b>Efficiently:</b> Response immediate and consistent.
1	<b>Somewhat efficiently:</b> Delayed in response. Performed with difficulty. Slowly in response.
0	<b>Inefficient:</b> Unsuccessfully performed. Infant appears disorganised. Infant shows panic: discomfort and may cry.

These numbers reflect a change in ability. A number 2 reflects the typical outcome expected for 6-to-7-months-old infants. The items provided a raw score for a sub-domain, a total score for a domain and VEMTT. Table 4.7 illustrates the summary sheet of calculated score for items, domains and total score for VEMMT. A typically developing 6-to-7-months-old infants is likely to obtain a score of 100%. The score obtained therefore can be used for describing the individual item, sub-domain and domain and a profile is obtained that can serve as a basis for further treatment or referral.

Table 4.7: A summary sheet of calculated scores

Voluntary Eye Movement Measurement Tool VEMMT						
<b>Attention</b>	<b>22. Disengagement</b>					
	Definition: The ability to direct the fovea from an attended central or peripheral target to engage with another target in the visual fields. Disengaging from and shifting gaze to a salient stimulus is a prerequisite for early exploration, reaching, and communication.					
			<b>Notes</b>	<b>Item Score</b>	<b>Sub Domain Score</b>	<b>Domain Score</b>
		2				
		1				
		0				
			Total item score: Disengagement			
	<b>23. Attention holding</b>					
	Definition: Attention holding is the maintenance of a stimulus which is intricate or novel. It is reflected by how long the infant engages in cognitive activity involving a stimulus.					
		2				
		1				
		0				
			Total item score: Attention holding			
	<b>24. Attention getting</b>					
	Definition: Attention-getting is considered the initial orientation or alerting to a stimulus and can be observed in head-turning or a gaze shift toward a large, bright object presented in the CFV or PVF.					
		2				
	1					
	0					
		Total item score: Attention getting				
<b>25. Joint attention</b>						
Definition: JA refers to the infant's ability to follow the direction of the gaze or gesture of others to share a common point of reference. Initiation and cycle of JA involve alternating looking by first looking at an object, making eye contact with another individual to share the attention of the object and then look at the object again.						
	2					
	1					
	0					
		Total item score: Joint attention (JA)				
<b>26. Sustained attention and self-regulation</b>						
Definition: The process of self-regulation involves the capacity to modulate mood, self-calm delay gratification and tolerated transitions of activities. Sustained attention is the ability to direct and focus cognitive activity on specific stimuli.						
	2					
	1					
	0					
		Total item score: Sustained attention and self-regulation				
<b>Total score for the domain: Attention</b>						
<b>VEMMT TOTAL SCORE</b>						

DOMAIN A: FUNCTIONAL VISION FOR PARTICIPATION	
Near task work	
Social interaction	
<b>Domain A: Total score</b>	

DOMAIN B: GAZE HOLDING	
<b>Domain B: Total score</b>	

DOMAIN C: GAZE SHIFTING	
Smooth pursuit (SPEM)	
Gaze pursuit (GP)	
Saccades	
<b>Domain C: Total score</b>	

DOMAIN D: ATTENTION	
<b>Domain D: Total score</b>	

VEMMT TOTAL SCORE	
DOMAIN A	
DOMAIN B	
DOMAIN C	
DOMAIN D	
<b>TOTAL SCORE FOR VEMMT</b>	

## 4.5.2 Interpretation of the results

As a response for each item is expected to be immediate and consistent for a typically developing 6-to-7-months-old infant, a score close to the expected typical outcome indicates that an infant requires further monitoring and, or, an intervention program. A score below the expected typical outcome means that the infant needs to be referred for further investigation and examination. Table 4.8 outlines the quality of performances which are colour coded.

### 4.8: Interpretation of the results

INTERPRETATION OF THE RESULTS.	
<b>RATING SCORE 2: EFFICIENTLY</b>	<b>HAS REACHED THE EXPECTED TYPICAL OUTCOME</b>
A score 2 indicates that the infant appears to be doing well in that developmental domain.	
<b>RATING SCORE 1: SOMEWHAT EFFICIENT</b>	<b>A SCORE CLOSE TO THE EXPECTED TYPICAL OUTCOME</b>
A score of 1 indicates that and infant need occupational therapy with further monitoring.	
<b>RATING SCORE 0: INEFFICIENT</b>	<b>A SCORE BELOW TO THE EXPECTED TYPICAL OUTCOME</b>
A score of 0 indicates that the infant needs to be referred for further investigation and examinations.	

## 4.6 USER QUALIFICATION

The VEMMT was developed for OTs and other healthcare professionals working in the early intervention field, with knowledge and clinical experience of atypical development in infants in the first year of life. It is highly recommended to practice this measurement tool on five typical infants between 6-months 1 day and 6-months 30/31 days before utilizing it on atypical infants or infants at risk.

## 4.7 ERROR OF MEASUREMENT

The first steps have been taken towards the development of a measurement tool. The scores must be interpreted with caution. Further validation of the scale needs to follow. The VEMMT has shown promising results.

## 4.8 CONCLUSION

This chapter detailed phases I and II. The construct was identified, defined and analysed in Phase I and in Phase II the construct was developed and constructed. The following Chapter 5 focuses on Phase III, the establishment of content validity.

# CHAPTER 5

## CONTENT VALIDITY

### PHASE III

---

#### 5.1 INTRODUCTION TO CONTENT VALIDITY

The VEMMT was constructed based on theory, clinical experience, reviewing existing VEM instruments/ tools in children and in infants, personal communication with authors/publishers, consultations with experts in the ophthalmology-neurology field and clinical experience. The construct of the VEMMT were conceptually defined and developed and is illustrated as Phase I and II, already described in Chapter 4 (cf. Table 4.1). The current version of the VEMMT reflects the 6-to-7-months-old infant's capability for using VEMs in naturalistic interaction with persons, objects or environment. In Phase III content validity of the VEMMT was established. Content validity refers to the degree to which the content of the items reflects the content domain of interest (Polit & Beck, 2018). Furthermore, it assesses the degree to which elements of an instrument are relevant to, and representative of, the targeted construct for a particular assessment purpose (Lynn, 1986). The primary goal of content validation involves inviting experts to evaluate the validity of the domains, sub- domains, items in order to retain the best items which are believed to adequately measure a desired content domain (cf. Table 3.1).

#### 5.2 STUDY DESIGN

For content validity a quantitative design was followed. Three experts in different disciplines were requested to voluntarily evaluate a set of items in the form of a questionnaire. Hennink and Hutter (2020) explained that a quantitative approach relied on statistical calculation on the appropriateness and clarity of items. It allowed the researcher to make decision to retain, alter or delete items from the VEMMT (Lynn, 1986).

#### 5.3 STUDY POPULATION AND SAMPLE SIZE

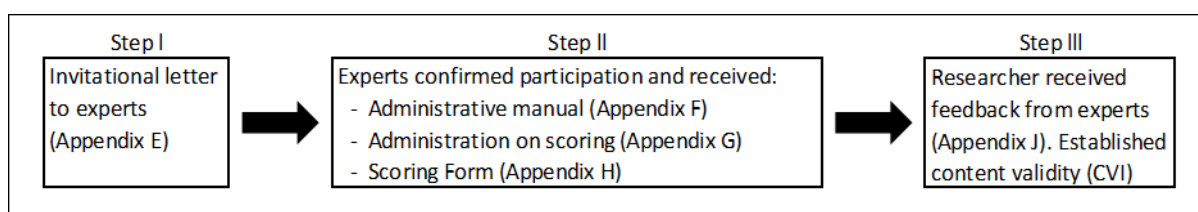
A review panel of three experts in the paediatric field of neuropsychology, optometry and occupational therapy were purposefully selected and invited to evaluate the

content validity of the VEMMT. The role of experts was fundamental in clarifying, adding, and/or modifying the necessary aspects in this specialised early neurological developmental field. These experts are involved in some aspect of voluntary eye movements with infants clinically.

## 5.4 DATA COLLECTION

To determine how adequately the newly developed VEMMT measures what it is claimed to measure, systematic steps were followed to establish content validity. The steps taken in order to establish content validity are illustrated in Table 5.1.

Table 5.1: Steps taken to establish content validity of the VEMMT



## 5.5 INVITATIONAL LETTER TO EXPERTS

A personalized email invitation was sent to the 3 experts. Each email outlined the reasons that they were selected, the purpose of the study, aims, objectives and the significance. Once the experts agreed to participate, specific documents were emailed to them which included the:

- VEMMT administration user manual (cf. Appendix F),
- administration and criteria for scoring (cf. Appendix G),
- scoring form of the VEMMT (cf. Appendix H), and
- validity scoring form which was to be completed by the expert (cf. Appendix J).

The experts participated voluntarily and were free to discontinue at any time. The three experts scrutinized the newly developed VEMMT to determine whether the domains, sub-domains and measurable items represents the construct being measured. The expert panellist completed the tasks at their own convenience and returned the feedback document once done. The COVID-19 pandemic caused a delay in this phase of the study as it disrupted the expert's way of working which subsequently led to all of them requesting an extension for submission of their

feedback. This delayed the process for data collection in this Phase by approximately four months.

The expert panel members rated the newly developed VEMMT based on the 4 domains, 5 sub-domains and 21 items as illustrated in Table 5.2. Assessment of domain 4, consisted of 5 attentional items (26 items in total) and refers to how, and at what pace, attentional performances proceed during the measurement. The VEMMT is conducted by observing object-visual related actions performed during interaction with toys from the VEMMT test kit. Twenty-six test items described different actions and attention and are scored in a 3-point scale, rating the quality of performance.

Table 5.2: The VEMMT are clustered in 4 domains, 5 sub-domains and 26 items

Domain	Sub-domain	Items
<b>A.Functional vision for participation</b>	<b>1.Near task work</b>	Look, reach, grasp, hold and release rattle with the right hand
		Look, reach, grasp, hold and release rattle with the left hand
		Looking, reaching, touching and holding a ball, with both hands to midline
		Adaptive reach with tactile input
	<b>2.Social interaction</b>	Peek a Boo
		Gaze following (Left; Right)
<b>B.Gaze holding</b>		Muscle balance in nine directions
		Direct penlight reflection
		Ocular alignment cover/uncover (Right ;Left eye)
		Convergence
<b>C.Gaze shifting</b>	<b>3.Smooth pursuit eye movement (SPEM)</b>	Horizontal SPEM
		Vertical SPEM
		Circular clockwise SPEM
		Circular anti-clockwise SPEM
	<b>4.Gaze pursuit (GP)</b>	Gaze pursuit from infant's left to right
		Gaze pursuit from infant's right to left
	<b>5.Saccades</b>	Fixation shift paradigm (Left; Right; Above)
		Gap shift paradigm (Left; Right)
		Express saccades
		Pupillary response (Left/Right).
		Exogenous saccades/ blink response
	<b>D.Attention</b>	
		Attention holding
		Attention getting
		Joint attention
		Sustained attention and self-regulation

## 5.6 IDENTIFIED RELEVANT ITEMS FOR THE ESTABLISHMENT OF CONTENT VALIDITY

To establish content validity the researcher compiled a 21-item-questionnaire on a rating form (Appendix J) and included:

- the purpose of the VEMMT (3 items),
- identifiable measurable criteria (13 items), and
- guidelines for procedures (5 items).

Table 5.3 illustrated the items identified by the researcher for consideration by the experts for the establishment of content validity.

Table 5.3: Identified items to be rated by the experts

<b>A. PURPOSE OF THE STUDY</b>	
<b>Item</b>	<b>Description</b>
1	Identified domains, sub-domains and items represents the typical infant between 6-to-7-months of age.
2	Defined domains, sub-domains and measurable items are applicable for the VEMMT.
3	The new developed VEMMT achieved its desired purpose.
<b>B. IDENTIFIABLE MEASURABLE CRITERIA</b>	
<b>Item</b>	<b>Description</b>
4	Content of the user administration manual is comprehensive and applicable for the VEMMT.
5	General guidelines are clear and understandable.
6	The set-up of room/equipment are well structured.
7	Holistic parental guidelines (Posture of infant).
8	Items represent eye movements for functional vision.
9	Timeline for the administration is appropriate for the 6-to-7-months old infants.
10	Flow and sequence of the domains, sub-domain and items.
11	Selected toys are appropriate.
12	Specifics of the measurements, placements of toys and stimulus cards.
13	Illustrations well designed for the VEMMT (Path, placements and distance of the target).
14	Criteria describes expected typical outcome.
15	Prompts well defined and appropriate.
16	Appropriateness of use of distractors and breaks.
<b>C. GUIDELINES FOR PROCEDURES</b>	
<b>Item</b>	<b>Description</b>
17	Items are clear and understandable.
18	Semantics: Easy to read and formatted well.
19	Rating scale is efficient.
20	Criteria for scoring of items.
21	Scoring form.

## 5.7 PURPOSE OF THE STUDY

The purpose of the study was to develop a measurement tool that can be used in a clinical setting for the identification of atypical VEMs influencing functional vision for participation. Early therapeutic intervention options will benefit developmental delay infants as a class enhancing neuroplasticity. The VEMMT will also help to inform policy makers and government in their decision on investment on early childhood development. Most importantly, OTs will ultimately contribute new information to add to the body of knowledge about the profession with a focus on premature infants.

## **5.8 IDENTIFIABLE MEASURABLE CRITERIA FOR VOLUNTARY EYE MOVEMENT MEASUREMENT TOOL**

The defined domains, sub-domains with the measurable indicators reflect the 6-month-old infant's capability for using VEMs in naturalistic interaction with persons, objects or the environment.

Typical development of VEMs was synthesised according to identified observable measurable criteria example target type, testing distance, extent of excursion, path of the target movement, ocular and environmental conditions and posture. An in-depth, holistic approach was used to identify, analyse and define the domains, sub-domains, and the items that related to functional vision for participation in communication, social interaction, near task and daily living activities, orientation and mobility. The VEMMT was conducted by observing VEMs movements performed during social interactions, near-task, mobility and orientation activities with attention.

## **5.9 GUIDELINES FOR PROCEDURES**

The development model of Miller et al., (2011) was key to the observable, measurable items identified and defined for the construction of the VEMMT. To ensure reliable results, examiners should become familiar with the administrative user manual (**cf.** Appendix F), administration procedures with scoring criteria (**cf.** Appendix G). The play session was conducted for about 20 min and video recorded. By scrutinizing the video recording, scoring was conducted in line with the criteria specified in the VEMMT manual and each item were delineated on the VEMMT scoring form (**cf.** Appendix H).

## **5.10 CONTENT VALIDITY OF THE VOLUNTARY EYE MOVEMENT MEASUREMENT TOOL**

Expert agreement, also called as measured domain, determines the content validity stratification (content-related) (Retnawati, 2016). The VEMMT is shown to be valid if the experts believe that the VEMMT measures the mastery abilities defined in the domains, sub-domains and items. The content validity index was established based on the judgements of three experts' knowledge, experience and specialization. This method is derived from the rating of the content relevance of the items on an instrument/tool using a 4-point ordinal rating scale (Lynn, 1986). Content validity

index is flexible as it requires a minimum of three experts. It offers practicality in terms of time and cost. By making use of the CVi it allows the researcher to make decisions to retain or delete items from a measurement tool/instrument through the calculation of CVi (Tojib & Sugianto, 2006).

### 5.11 RATING SCALE USED BY EXPERTS

Content validity focusses on agreement of relevance. The experts used a 4-point ordinal rating scale, where 1 connotes an irrelevant item and 4 a highly/extremely relevant item as illustrated in Table 5.4.

Table 5.4: Description, percentage and meaning of the rating point scale

Scoring	Description of Relevance	Action to be taken from researcher
1	Complete irrelevant	Discard item/replace item
2	Minimal relevant	Unable to assess relevance, item revision is needed.
3	Very relevant	Need minor alterations
4	Extremely relevant	No correction

### 5.12 CONTENT VALIDITY INDEX

The degree of agreement among the participants regarding the importance of the content is quantified into one coefficient V-value (Lynn 1986). The validity coefficient index proposed by Aiken (1985) was applied and is described in Table 5.5.

Table 5.5: Validity coefficient proposed by Aiken (1985)

$V = \frac{\sum s}{n(c-1)}$		
V	=	Value of validity coefficient of Aiken
s	=	Scores assigned by each rater minus the lowest score in the used category (s=r-lo, with r= rater category selection score and lo the lowest score in the scoring category)
n	=	Is the number of raters/can be replaces by m that represents the number of items in the instrument
c	=	The number of categories that raters can choose
The V index value ranges from 0-1. The closer an item to 1 the better it is, because it is more relevant to the indicator.		

### 5.13 CRITERIA FOR CONTENT VALIDITY USING THE AIKEN INDEX

Interpretation of the validity index is detailed in Table 5.6.

Table 5.6: Criteria for content validity using the Aiken index

Validity index (V)	Interpretation
$0 \leq V \leq 0.4$	Minimally valid
$0.4 < V \leq 0.8$	Very valid
$0.8 < V \leq 1$	Extremely valid

### 5.14 RESULTS FOR ESTABLISHING CONTENT VALIDITY

The results of the content validity as assessed by the 3 experts of the entire VEMMT and each item are listed in Table 5.7. The criteria for content validity using the Aiken index are very valid if the Aiken validity index is more than 0.8 (Aiken 1985).

Table 5.7: Validity coefficient index results of VEMMT

A. PURPOSE OF THE STUDY							
		Expert 1	Expert 2	Expert 3			
Item	Description	Score	Score	Score	$\sum S$	Validity coefficient index (CVI)	Interpretation of the Aiken Index
1	Identified domains, sub-domains and items represents the typical infant between 6-to-7-month old infants.	4	4	4	9	1	Extremely valid
2	Defined domains, sub-domains and measurable items are applicable for the VEMMT.	4	4	4	9	1	Extremely valid
3	The new developed VEMMT achieved its desired purpose.	4	4	4	9	1	Extremely valid
<b>CVI: Purpose of the study</b>						1	Extremely valid

B. IDENTIFIABLE MEASURABLE CRITERIA							
		Expert 1	Expert 2	Expert 3			
Item	Description	Score	Score	Score	$\sum S$	Validity coefficient index (CVI)	Interpretation of the Aiken Index
4	Content of the user administration manual is comprehensive and applicable for the VEMMT.	4	3	4	8	0.88	Extremely valid
5	General guidelines are clear and understandable.	4	4	3	8	0.88	Extremely valid
6	The set-up of room/equipment are well structured.	4	4	4	9	1	Extremely valid
7	Holistic parental guidelines (Posture of infant).	4	4	4	9	1	Extremely valid
8	Items represents functional vision.	4	4	4	9	1	Extremely valid
9	Timeline for the administration is appropriate for the 6-to-7-month old infants.	4	4	4	9	1	Extremely valid
10	Flow and sequence of the domains, sub-domain and measurable items.	3	4	4	8	0.88	Extremely valid
11	Selected toys are appropriate.	3	3	4	7	0.77	Very valid
12	Specifics of the measurements, placements of toys and stimulus cards.	4	3	4	8	0.77	Very valid
13	Illustrations well designed for the VEMMT (Path of the target movements)	4	4	4	9	1	Extremely valid
14	Criteria describes expected typical outcome.	4	4	4	9	1	Extremely valid
15	Prompts well defined and appropriate.	4	4	4	9	1	Extremely valid
16	Appropriateness of use of distractors and breaks.	4	4	4	9	1	Extremely valid
<b>CVI: Identifiable measurable criteria</b>						0.94	Extremely valid

C. GUIDELINES FOR PROCEDURES							
		Expert 1	Expert 2	Expert 3			
Item	Description	Score	Score	Score	$\sum S$	Validity coefficient index (CVI)	Interpretation of the Aiken Index
17	Items are clear and understandable.	4	3	4	8	0.88	Extremely valid
18	Semantics: Easy to read and formatted well.	3	3	4	7	0.77	Very valid
19	Rating scale is efficient.	4	4	4	9	1	Extremely valid
20	Criteria for scoring of items.	4	4	4	9	1	Extremely valid
21	Scoring form.	4	4	4	9	1	Extremely valid
<b>CVI: Guidelines for procedures</b>						0.93	Extremely valid

<b>VEMMT Content Validity Aiken Index</b>	<b>0.96</b>	<b>Extremely valid</b>
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#### **5.14.1 Content validity index for entire voluntary eye movement measurement tool**

The judgement of the 3 experts were used to demonstrate the content validity using the Aiken formula. Table 5.7 revealed the expert's assessments of the entire VEMMT that included the purpose, measurable criteria and the procedures. The results showed a content validity index of 0.96 for the entire VEMMT.

#### **5.14.2 Content validity index for individual items**

Table 5.7 shows that from the 21 items, 3 items were very valid, and 18 items were extremely valid. Three items needed minor alterations.

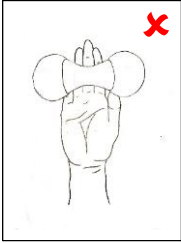
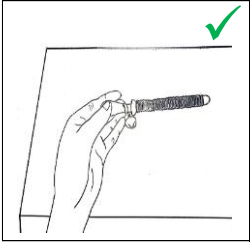
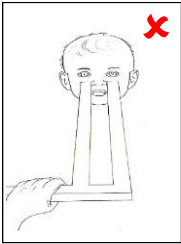
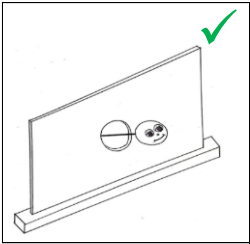
### **5.15 DATA ANALYSIS**

Feedback from the participants was reviewed. The entire VEMMT have an extremely valid Aiken's index of 0.96 which implies that the entire VEMMT is very solid and extremely relevant to measure VEMs in 6-to-7-months-old infants.

### **5.16 MINOR ALTERATIONS**

Feedback from the experts was reviewed for item improvement. Table 5.8 shows the minor alterations made as suggested by the experts with an explanation.

Table 5.8: Minor alterations made by the researcher as suggested by the experts

Content validity item.	Description	Minor alteration
11	Selected toys are appropriate	<p><b>VEMMT item 1:</b> Look, reach, grasp, hold and release.</p> <div style="display: flex; justify-content: space-around; align-items: center;">   </div> <p><b>Reason:</b> Created space for placement on rattle.</p>
12	Specifics of the measurements, placements of toys and stimulus cards.	<p><b>VEMMT item 10:</b> Convergence.</p> <div style="display: flex; justify-content: space-around; align-items: center;">   </div> <p><b>Reason:</b> Limit background clutter.</p>
18	Semantics: Easy to read and formatted well	<p><b>Guidelines for procedures:</b> Additional cards for administration and prompts were added. <b>Reason:</b> Easier to read with a bigger font (<b>Appendix L</b>).</p>

## 5.17 ADDITIONAL FEEDBACK

An in-depth, holistic approach was used to identify, analyse and define the domains, sub-domains and the items that related to functional vision for participation in communication, social interaction, near task activities, orientation and mobility. The newly developed clinical VEMMT supports infants with developmental difficulties and their families, provides a mechanistic understanding of disorders, helps define prognoses, documents the effects of interventions and estimates the national prevalence of developmental delays in the visual-perception and action systems.

## 5.18 ERRORS OF MEASUREMENT

Ideally a larger panel of experts is recommended for the evaluation of any newly developed tool including the VEMMT. This study research is limited in its population therefore, this validation should continue for as long as the VEMMT is being used. No matter how well designed the validation study is, elements of chance of error,

and situations-specific factors that can over- or under inflate the estimate of validity are always present.

### **5.19 CONCLUSION**

The results of the content validation by the judgment experts showed that overall, the VEMMT is extremely valid. Therefore, the VEMMT can be used appropriately to measure voluntary eye movement in 6-to-7-months-old infants.

# CHAPTER 6

## PILOT THE NEWLY DEVELOPED VOLUNTARY EYE MOVEMENT MEASUREMENT TOOL PHASE IV

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### 6.1 INTRODUCTION

The dynamic nature of development is perhaps the first and most important challenge for the timely identification of atypical behaviours in infants. Development in most infants proceeds at a predictable rate and in a predictable fashion with extensive variations (King-Dowling et al., 2016). It is the responsibility of the clinician to identify whether these variations are reasons for concern. The role of vision in human development and human relationships has long been recognised in this context (Crollen & Collignon, 2020). The visual system allows the infant to extract information from the environment and is linked to the infant's perceptual, sensory-motor and emotional development (Ortibus et al., 2019).

In Phase IV the newly developed VEMMT was tested as planned according to the design of this research (cf. Table 3.1). The pilot study validated the VEMMT by administering it to typically developing infants 6-months day 1 up to 6-months day 30/31 (6-to-7-months old infants).

The objectives of the pilot study were to:

- refine the VEMMT as developed during Phases I, II and III,
- determine if the inclusion criteria used represents the typical 6-to-7-months old infant,
- determine whether the developed instruments for each domain, sub-domain and items were adequate and appropriate for 6-to-7-months old infants,
- ensure that the administrative user manual, the criteria for administration and scoring were adequate and appropriate for 6-to-7-months old infants, and

- reveal its purpose and its suitability for both the clinicians, PCGs and the infants.

In this chapter the main findings of the pilot study are presented and discussed in alignment with literature control for confirmation, acceptance, adaptations or the rejection to the construct of the newly developed VEMMT. The researcher tested the various aspects that were involved without the intention to generalise the findings.

## **6.2 COVID-19 PANDEMIC IMPACT ON THE PILOT STUDY**

The COVID-19 pandemic brought an extraordinary disruption to Phases III and IV for completion. The impact of the pandemic has led to changes in implementation with respect to the sampling method and size.

### **6.2.1 General impact of the pandemic from a researcher's perspective**

It felt as if the clock had stopped ticking for this research and the researcher fought to keep the study on track but with ultimate delay in results. The researcher also had to deal with, amongst others:

- physical, psychological fatigue and the long-term health consequences after being infected,
- impacts on financial income, and
- stressful events related to close surroundings including the loss of immediate relatives.

## **6.3 STUDY POPULATION**

Typical developing infants between 6-months day 1 up to 6-months day 30/31 (6-to-7-months old infants) formed the sample for this phase of the study.

## **6.4 SAMPLING METHOD**

Although the researcher received permission letters from the Department of health in North West Province to conduct the pilot study at the clinics in the district, it was no longer possible due to the COVID-19, pandemic. The COVID-19 protocol was followed (**cf.** 3.6.4). The pilot continued on this basis by availability and health situation. Snowballing method was used by sending asking paediatricians, general practitioners and clinics to distribute invitational letters to PCGs.

### 6.4.1 Sampling size

The research ethics committee granted an ethical certificate, on request by the researcher, to reduce the study sample size. The sample size was categorised into age groups and the numbers were reduced. The total number of infants and the PCGs were eight and is illustrated in Table 6.1. Initially there were 10 infants in the group. The reason for the withdrawal of two participants was as their score on the AQS-3 were below (cf. Table 6.5) and close to the cut-off score which was set as an inclusion criterion.

Table 6.1: Study sample

Age group	Number of infants included in the research project
6months - Day 1-7	2
6months - Day 8-14	2
6months - Day 15-21	2
6months – Day 22-30/31	2
<b>Total</b>	<b>8</b>

## 6.5 INCLUSION CRITERIA

Inclusion of participants followed four steps and is illustrated in Table 6.2.

Table 6.2: Overview of the inclusion criteria

Step 1		Step 2	Step 3	Step 4	
Biographical information	Covid testing	Alert state of the infant	AQS-3 Questionnaire	Visual functions	Signed consent
* Age range: 6-to-7-months. * Infants from 37 weeks to full term gestation * Normal birth weight (2,500 grams or above). * No diagnosed disability	Both the researcher and PCG show negative test 72 hours prior to the appointment	The infant should be rested and fed. An alert state 4 is defined as alert with a bright look and focus is on visual or auditory stimuli with minimum movements (cf. 2.5)	Screen infants for developmental delays for: *Communication *Gross motor *Fine motor *Problem solving *Personal-social (cf. Table 6.5)	* Visual acuity * Contrast sensitivity * Visual field  (cf. Table 6.7)	PCG over the age of 18 years

Step 1 included the biographical information, the alertness state of the participant and COVID-19 testing. Step 2 included the administration of the ASQ-3 (cf. 6.5.3), completed by the PCG and scored by the researcher. Step 3 included the

examination of the participant’s visual functions parameters (**cf.** 6.6). These three steps led to the final inclusion of participants for the pilot study, step 4, a signed consent form, from the PCG over the age of 18 years (**cf.** Appendix C and D). The participants that passed all the expected parameters were included in the study.

### 6.5.1 Interpreter

Families sometimes need an interpreter to assist with the understanding of instructions, or with the discussions of the results. The user guidelines of the ASQ-3 were used for the interpreter’s role and is summarised in Table 6.3.

Table 6.3: ASQ-3 user’s guide for an interpreter

<b>Role of interpreter</b>	Ideally the interpreter is verbally and culturally proficient in both languages.
<b>Duties of an interpreter</b>	To set aside emotions and opinions. Understand the VEMMT and relevant terminology that will be used during the measurement. The interpreter will be prepared prior to the VEMMT to sort out any confusion.
<b>Items not culturally appropriate</b>	The interpreter should be familiar with the family's culture and the meaning of terms and actions of the culture. The interpreter should speak slowly and clearly and ask PCG to provide feedback on any items that were difficult to understand or observed to items that are culturally inappropriate.
<b>Administration</b>	Sitting in a triangle formation with the provider and family member across from each other and the interpreter seated in the side. Talk directly to the family rather than to the interpreter. After VEMMT is completed respond to the families concerns and questions. Through the interpreter summarize what has been done.
<b>Keep record of culture-related notes</b>	The interpreter created a main file for any notes she/he made about items that were confusing or culturally inappropriate for future reference.

### 6.5.2 Biographical information

Typically developing infants were invited to participate in this research project. Typical development is defined as a behaviour with complexity and variability for a specific age range (Bly & Ariz, 1995). Table 6.4 illustrates the results on biographical information.

Table 6.4: Results of biographical information

Inclusion - Step 1								
P	AGE GROUP	BIOGRAPHICAL INFORMATION				COVID		Alert State 4
		AR	FT	NB	NDD	P	N	
1	6-MNTHS DAY 3	✓	✓	✓	✓		✓	✓
2	6-MNTHS DAY 5	✓	✓	✓	✓		✓	✓
3	6-MNTHS DAY 8	✓	✓	✓	✓		✓	✓
4	6-MNTHS DAY 13	✓	✓	✓	✓		✓	✓
5	6-MNTHS DAY 14	✓	✓	✓	✓		✓	✓
6	6-MNTHS DAY 17	✓	✓	✓	✓		✓	✓
7	6-MNTHS DAY 19	✓	✓	✓	✓		✓	✓
8	6-MNTHS DAY 20	✓	✓	✓	✓		✓	✓
9	6-MNTHS DAY 29	✓	✓	✓	✓		✓	✓
10	6-MNTHS DAY 30	✓	✓	✓	✓		✓	✓

Note: P = Participant, AR = Age Range 6-to-7-months, FT = Full Term, NB = Normal Birth, NDD = No Diagnosed Disability, P = Positive, N = Negative

The results illustrate that the biographical information of all ten participants were in the typical range.

### 6.5.3 Ages & stages-3 questionnaire

Early and accurate identification of infants who have developmental delays is key to the timely delivery of early intervention services. The 6-month ASQ-3 is a parent-completed child monitoring system that meets the criteria for a first-level comprehensive screening.

ASQ-3 has 30 questions about a child’s developmental abilities and is organised in five items to be scored:

- Communication
- Gross motor
- Fine motor
- Problem solving
- Personal-social

Although the questionnaires are designed to be completed by the PCG, the ASQ-3 requires professional involvement. Parents/caregivers/guardians completed the ASQ-3 under the supervision of the researcher with or without an interpreter. Hsiao et al., (2017) found that the psychometric properties of using the ASQ-3 in both South Africa and Zambia through a combination of caregiver-report and direct observations is feasible. A description of the ASQ-results of 10 infants are presented in Table 6.5.

Table 6.5: ASQ-3 results

p	AGE GROUP	ASQ COM	ASQ GM	ASQ FM	ASQ PS	ASQ PERS	C	I
1	6-MNTHS DAY 3	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	N	N
2	6-MNTHS DAY 5	BELOW CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	N	N
3	6-MNTHS DAY 8	ABOVE CUT-OFF	CLOSE TO CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	N	N
4	6-MNTHS DAY 13	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	N	N
5	6-MNTHS DAY 14	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	N	N
6	6-MNTHS DAY 17	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	N	N
7	6-MNTHS DAY 19	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	N	Y
8	6-MNTHS DAY 20	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	N	Y
9	6-MNTHS DAY 29	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	N	N
10	6-MNTHS DAY 30	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	ABOVE CUT-OFF	N	Y

Note: P = Participant, COM = Communication, GM = Gross Motor, FM = Fine Motor, PS = Problem Solving, PERS = Personal-Social, C = Concerns, I = Interpreter

Y = YES
N = NO

AGE GROUP 6-MONTHS
WEEK 1 - 2 PARTICIPANTS
WEEK 2 - 3 PARTICIPANTS
WEEK 3 - 3 PARTICIPANTS
WEEK 4- 2 PARTICIPANTS

EXCLUDED FROM STUDY	REASON
PARTICIPANT 2	COMMUNICATION - BELOW CUT-OFF
PARTICIPANT 3	GROSS MOTOR CLOSE TO CUT OFF

As illustrated in Table 6.5, there were no concerns expressed by the PCGs. On three occasions an interpreter was used to assist with the completion of the questionnaire. Two participants were excluded from the study. The results illustrate

that the communication score of one initial participant, aged 6-months 5 days of the ten participants scored below cut-off and was thus excluded from the study. Another participant aged 6-months 8 days was close to the cut-off score and was also excluded from the study. The total number of infants and the PCG that were finally included was eight. The scores obtained for the initial ten infants, for each developmental item, during administration of the ASQ-3 are summarised in Appendix K. An intervention activities program was given to the parents of the excluded participants.

#### **6.5.4 Ethical consideration for excluded participants**

The parents of the two excluded participants were informed, empathetically, about the results. Both parents had chosen to follow the intervention activities with a follow-up session at the practice of the researcher. The ASQ-3 intervention activities for the age group 6-8-months were taught to the parents in such a way that could have rendered the positive outcome of the mastering of the activities.

### **6.6 VISUAL FUNCTIONS**

Visual acuity, VF and CS are the most significant measurable visual functions. Reduced input due to a dysfunction in the VA, VF and CS reduce development (Colenbrander & Fletcher, 2018). Visual functions describe how the eye and the basic visual system function in terms of threshold performances for VA, CS and VF that are tested one at a time (Mercuri et al., 2007).

Visual acuity is the ability to resolve or recognise fine details and the value usually refers to the size of the smallest optotypes that the child can recognise (Hyvärinen, 2013, 2019). Children who develop good acuity may go on to exhibit features of cognitive and perceptual-motor visual skills. Contrast sensitivity is a measure of the minimum difference in subtle shades of grey that can be detected by the human visual system (Atkinson, 2002). The visual field is the extent in space in which objects are visible to a stationary eye, as well as a measure of the area that can be seen simultaneously by the eyes at any moment (Scheiman et al., 1995). The large field of vision allows the infants to easily manoeuvre safely in space. Voluntary eye movements and memory assist to increase the functional size of the visual field

(Heidary, 2017). The visual function parameters required for inclusion into the sample are defined in Table 6.6 followed by the results.

Table 6.6: Definition of the visual function parameters

<b>Parameter and Method</b>	<b>Definition</b>	<b>Author/s</b>
Visual acuity (VA). Teller acuity cards.	Visual acuity is the ability to resolve or recognise fine details and the value usually refers to the size of the smallest optotypes that the child could recognise. For infants the preferential looking paradigm was used to measure VA by using the grating Teller acuity cards.	Teller et al., 2005. Teller et al., 1986.
Contrast sensitivity (CS). Hiding Heidi contrast cards.	Contrast sensitivity measures the ability to see differences in the amount of light reflected from adjacent surfaces. This ability allows a person to notice edges and shadows that define objects and also shows the depth and placement in space.	Atkinson, 1984.
Visual Fields (VF). Confrontation method (Kinetic field testing).	The visual field is the extent in space in which objects are visible to a stationary eye.	Lewis & Maurer, 1992.

### 6.6.1 Visual function results

The visual functions measured are presented in Table 6.7 for the eight participants included in the pilot study. All eight infants between 6-to-7-months of age met the criteria in terms of visual function and were thus included in the study. The researcher has observed, in the clinical setting, that a developmental delay leading to difficulties in active participation in activities, may be found in infants who have difficulty in shifting and holding their gaze during eye movement assessments. The opposite i.e., that developmental delays as screened during the ASQ-3 may influence the infant's visual abilities, to shift and hold their gaze during functional

visual activities, can also be inferred. An inclusion scoring form (Appendix I) was compiled by the researcher.

Table 6.7: Visual function scores

Participant	Visual Acuity		Contrast Sensitivity		Visual Field		
	CY/CM	RESPONSE		RESPONSE	VF		RESPONSE
1	1.3	✓	Full Contrast	✓	Upper	45°	✓
	2.4	✓	25%	✓	Lower	30°	✓
	4.8	✓	5%	✓	Right VF	70°	✓
			1,25%	✓	Left VF	70°	✓
2	Excluded from study						
3	Excluded from study						
4	1.3	✓	Full Contrast	✓	Upper	45°	✓
	2.4	✓	25%	✓	Lower	30°	✓
	4.8	✓	5%	✓	Right VF	70°	✓
			1,25%	✓	Left VF	70°	✓
5	1.3	✓	Full Contrast	✓	Upper	45°	✓
	2.4	✓	25%	✓	Lower	30°	✓
	4.8	✓	5%	✓	Right VF	70°	✓
			1,25%	✓	Left VF	70°	✓
6	1.3	✓	Full Contrast	✓	Upper	45°	✓
	2.4	✓	25%	✓	Lower	30°	✓
	4.8	✓	5%	✓	Right VF	70°	✓
			1,25%	✓	Left VF	70°	✓
7	1.3	✓	Full Contrast	✓	Upper	45°	✓
	2.4	✓	25%	✓	Lower	30°	✓
	4.8	✓	5%	✓	Right VF	70°	✓
			1,25%	✓	Left VF	70°	✓
8	1.3	✓	Full Contrast	✓	Upper	45°	✓
	2.4	✓	25%	✓	Lower	30°	✓
	4.8	✓	5%	✓	Right VF	70°	✓
			1,25%	✓	Left VF	70°	✓
9	1.3	✓	Full Contrast	✓	Upper	45°	✓
	2.4	✓	25%	✓	Lower	30°	✓
	4.8	✓	5%	✓	Right VF	70°	✓
			1,25%	✓	Left VF	70°	✓
10	1.3	✓	Full Contrast	✓	Upper	45°	✓
	2.4	✓	25%	✓	Lower	30°	✓
	4.8	✓	5%	✓	Right VF	70°	✓
			1,25%	✓	Left VF	70°	✓

Table 6.7 illustrates the visual function scores. The table illustrates that the visual function scores of all eight participants to be in the typical range as expected for 6-to-7-months-old infants.

## 6.7 PILOT THE VOLUNTARY EYE MOVEMENT MEASUREMENT TOOL

The following checklist will assist an examiner to set-up the VEMMT. Table 6.8 is a general guideline checklist for an examiner.

Table 6.8: General guideline checklist

<b>CHECKLIST</b>		<b>Checked</b>
<b>Set up room</b>	Preparation of room: Video recording. Equipment – chair and desk. Environmental condition: <ul style="list-style-type: none"> <li>• Typically, illumination from overhead diffuse fluorescent lights.</li> <li>• Natural light can assist.</li> <li>• Avoid visual and auditory noisy surroundings.</li> <li>• Temperature of room between 20 - 22°Celsius.</li> </ul>	
<b>User qualification</b>	Healthcare professional with experience in the early intervention field.	
<b>Inclusion criteria of participant</b>	Met the criteria (cf. 6.5).	
<b>Positioning</b>	Supportive sitting position on lap of PCG. From desk to eyes of infant = 20 cm.	
<b>Regulatory state of infant</b>	Quiet alert state (State 4)	
<b>VEMMT kit</b>	Prepare toys before starting. Be familiar with each toy's purpose, stimulus card and floor plan on mat.	
<b>Procedures</b>	Be familiar with the instructions, timing, breaks, attempts, how to use distractors, prompts and warm-up. Familiar with the outcome of each test item.	
<b>Time</b>	Use the indicated speed of toy use and indicated time periods for play with toys.	

## 6.8 RESULTS OF THE VOLUNTARY EYE MOVEMENT MEASUREMENT TOOL

A total score of 52 indicated that the infant's VEM in function developed in a typical age range of 6-to-7-months-old infants. Table 6.9 illustrates the typical range. The domain, sub-domain and item scores indicated that the eight typically developing infants have reached the expected outcome criteria. Table 6.10 illustrates the domain and sub-domain scores of the eight typically developing infants.

Table 6.9: Typical expected score range for 6-to-7-months-old infants

DOMAIN A			DOMAIN B			DOMAIN C			DOMAIN D			VEMMT	
Functional Vision for Participation			Gaze Holding			Gaze Shifting			Attention				
	IS	TS		IS	TS		IS	TS		IS	TS	IS	TS
Near task work	8	8	Gaze Holding	8	8	SPEM	8	8	Attention	10	10		
Social interaction	4	4				GP	4	4					
						Saccades	10	10					
Total Score:	12	12	Total Score:	8	8	Total Score:	22	22	Total Score:	10	10	52	52

Note: IS = Infant score, TS = Typical score, SPEM = Smooth pursuit, GP = Gaze pursuit

Table 6.10: Domain and sub-domain scores

P	AGE GROUP	DOMAIN A FVP		DOMAIN B GH		DOMAIN C GS		DOMAIN D ATT		VEMMT
1	6-MNTHS DAY 3	NTW	8	GH	8	SPEM	8	ATT	10	52
		SI	4			GP	4			
						Saccades	10			
		TS	12	TS	8	TS	22	TS	10	
4	6-MNTHS DAY 13	NTW	8	GH	8	SPEM	8	ATT	10	52
		SI	4			GP	4			
						Saccades	10			
		TS	12	TS	8	TS	22	TS	10	
5	6-MNTHS DAY 14	NTW	8	GH	8	SPEM	8	ATT	10	52
		SI	4			GP	4			
						Saccades	10			
		TS	12	TS	8	TS	22	TS	10	
6	6-MNTHS DAY 17	NTW	8	GH	8	SPEM	8	ATT	10	52
		SI	4			GP	4			
						Saccades	10			
		TS	12	TS	8	TS	22	TS	10	
7	6-MNTHS DAY 19	NTW	8	GH	8	SPEM	8	ATT	10	52
		SI	4			GP	4			
						Saccades	10			
		TS	12	TS	8	TS	22	TS	10	
8	6-MNTHS DAY 20	NTW	8	GH	8	SPEM	8	ATT	10	52
		SI	4			GP	4			
						Saccades	10			
		TS	12	TS	8	TS	22	TS	10	
9	6-MNTHS DAY 29	NTW	8	GH	8	SPEM	8	ATT	10	52
		SI	4			GP	4			
						Saccades	10			
		TS	12	TS	8	TS	22	TS	10	
10	6-MNTHS DAY 30	NTW	8	GH	8	SPEM	8	ATT	10	52
		SI	4			GP	4			
						Saccades	10			
		TS	12	TS	8	TS	22	TS	10	

Note: P = Participant, FVP = Functional Vision for Participation, NTW= Near task work, SI= Social interaction, GH= Gaze holding, GS = Gaze Shifting, SPEM = Smooth pursuit, GP= Gaze pursuit ATT = Attention, TS = Total score.

The Table 6.10 illustrates that the VEMMT total score of all eight participants to be typical for 6-to-7-months old infants.

## **6.9 DISCUSSION**

A systematic clinical VEMMT was developed for typically developing 6-to-7-month-old infants. The demographic information overview of the participants was displayed. The sample size in the study was small but realistic in the circumstances of the COVID-19 pandemic. The inclusion criteria impacted further on the sampling process. The participants selected for this study were born at or after 37 weeks to full term gestation. All participants presented at birth a normal birth weight (2,500 grams or above) without any diagnosed disease or disability. They had scored in the typical range for visual functions and passed the developmental questionnaire, the ASQ-3. All participants' state of alertness were on a level four meaning they were focused without any fussiness. Eight participants matched the inclusion criteria. Informed, written consent for participation was obtained from the PCG of all participants.

The VEMMT was administered and scored. Eight typically developing 6-to-7-months-old infants who were included in this research study scored the maximum scores in all the items, indicating that the infants appear to be doing well and promote continued healthy development in VEMs for purposeful goal-directed actions for participation in near task work, activities of daily living, social interactions, mobility and orientation.

## **6.10 CONCLUSION**

The development of the central nervous system is not predetermined but depends on interaction with external factors. Development is dependent on the activity in the neural circuits. Nerve cells and neural circuits that are frequently used strengthen their connections, while those that are not used are weakened. The phrase "use or lose" reflects this principle and indicates how an exuberant number of nerve cells and neural pathways which exist in early phase of development are discarded because they are not used.

By 6-to-7-months of age the infant had developed the skill of adjusting the hand to an object, orienting and adjusting the grip based on visual clues and both upper extremities are brought together consistently. Smooth straight reaching pathway depends on the transformation of the visual space to a body-centered coordinate system.

Voluntary eye movements are a prerequisite for clear, stable and single vision (Atkinson, 2002) and represent a building block for learning and cognition upon which higher-order functions are constructed across early childhood. Voluntary eye movements and the organized purposeful actions are dramatic observable measurable behaviours. When compared to typically developing children VEMs and purposeful actions are observable behaviors.

The VEMMT is developed with literature control for confirmation. The VEMMT can support infants with developmental difficulties and their families, provide a mechanistic understanding of disorders, help define prognoses, document the effects of interventions and estimating the national prevalence of developmental delays in the visual-perception and action systems.

# **CHAPTER 7**

## **CONCLUSION, RECOMMENDATIONS AND LIMITATIONS**

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### **7.1 INTRODUCTION**

The vision of an infant is crude. As infants experience the visual environment through active participation during purposeful activities their vision continues to develop and rapidly improves with different visual capabilities emerging at different ages. The visual brain is highly malleable during early infancy and the maturation of visual functions depends on visual experience during the critical periods of development. Typical visual experience requires clear, unrestricted images in each eye and precise matching of the images of the two eyes. The neural control of VEMs is organised to optimize performance of functional vision that represents action and perception. The VEMMT is a valuable measurement tool for gathering information about an infant's functional vision system within the context of his/her overall development. This final chapter provides a conclusion to this study by outlining the value and benefits of the newly developed VEMMT, observed limitations of the study and providing recommendations aimed at further/future research studies.

### **7.2 VALUE OF THE VOLUNTARY EYE MOVEMENT MEASUREMENT TOOL**

The assessment of an infant's vision system is an integrated part of the total developmental assessment of the infant and helps in the formulation of intervention strategies and treatment principles.

### **7.3 CO-OPERATION WITH OTHER PROFESSIONALS**

It is frequently the case that a range of professionals other than OTs will be involved with the young infant in various ways with a true team approach being highly recommended. Occupational therapists will thereby have the opportunity to measure VEMs that relate to visual performance for development of perception and action. This will also provide the opportunity for multidisciplinary team members, to provide, holistic management strategies for infants at risk.

#### **7.4 SENSITIVE AND CRITICAL PERIODS ON VISUAL DEVELOPMENT**

Periods of rapid maturation in many sensory systems are associated with high levels of sensitivity to the quality and structure of the inputs from the environment. The VEMMT provides an assessment in the critical period of visual development as the VEMMT measures the visual behavior during purposeful visual experiences in 6-to-7-months-old infants. These visual experiences measured through VEMs are essential for development and performances. Atypical or limited behavioral repertoire of voluntary eye movements will disrupt development. During an early sensitive period, typical visual experiences such as near task work, social interactions, mobility and orientation are required to develop the full capacity of the visual system otherwise atypical VEMs causing atypical visual experiences will produce atypical visual processing for action and perception. The VEMMT thus provides valuable information of the neural organization of the brain.

#### **7.5 VOLUNTARY EYE MOVEMENT MEASUREMENT TOOL DOMAINS, SUB-DOMAINS AND ITEMS**

The aim of the study was to develop a clinical measurement tool for measuring VEMs in typical 6-to-7-months-old infants. The clinical significance of the VEMMT is that it allows for the early identification of atypical voluntary eye movements from the typical 6-to-7-months-old infants. The VEMMT was developed because the maturation of visual processing depends on VEMs and visual experience during the critical period in the first 6-months of life. Voluntary eye movements are the foundation to process visual information efficiently for recognition, memory, organized purposeful actions, and attention on an ever-changing environment in all cultures to promote communication, social participation, activities of daily living, near task work, mobility and orientation.

Occupational therapists thus, with the VEMMT, now have the opportunity to measure VEMs that relate to visual performances for development of perception and action for 6-to-7-months-old infants. Four domains, 5 sub-domains and 26 item activities were identified and defined that reflected the 6-to-7-months-old infant capabilities for using VEMs in a naturalistic interaction with persons, objects or environment in the occupational paradigm of a typical developing infant.

A theoretical exploration of existing literature on voluntary eye movement instruments/tools in children, personal communication with authors/publisher, consultation with experts and the researcher's clinical experience were of utmost importance for the identification of, defining and analysing the functional aspects of voluntary eye movement.

The activities used in the VEMMT for gaze holding and shifting incorporate complex neurology control systems as identified for a typical developing 6-to-7-months-old infants.

## **7.6 TARGETS, OBJECTS AND ENVIRONMENTAL CONDITIONS**

All toys, placement of targets, the excursions and path taken are predetermined according to a typical developing 6-to-7-months-old infant's daily life engagement. All toys are safe and do not include any small parts that can be dangerous for 6-month-old infants. The kit includes a well-designed and friendly user's manual, administration manual and scoring sheet.

## **7.7 BENEFITS OF THE VOLUNTARY EYE MOVEMENT MEASUREMENT TOOL**

- The VEMMT is developed for typical developing infants meaning it will differentiate typical from atypical eye movements that relates to visual performances for the development of perception and action in daily life. The VEMMT is part of the dynamic systems, a clinical significance to identify dynamic systems influencing purposeful behaviours.
- It is relatively inexpensive to perform the VEMMT and does not require laboratory support.
- The VEMMT is a clinical measurement tool that can support infants, with developmental difficulties, and their families; provides a mechanistic understanding of disorders; helps define prognoses; documents the effects of interventions and estimates the national prevalence of developmental delays in the visual-perception and action systems.
- Consideration of the nature of the sensory/motor processing which would seem to be needed for development, led clinicians to believe that infants need specific abilities and skills in the dynamic systems for purposeful directed actions and perception. Voluntary eye movements are a pre-

requisite for clear stable vision for function. Thus, knowledge of the control of VEMs aids the interpretation of disorders and may advance an understanding of how the brain controls movement of the eyes for purposeful goal-directed actions for development.

- Any health professionals who are knowledgeable regarding sensory-motor-perceptual development of infants and have experience in examination of, and intervention for, preterm and full-term high risks infants under the age of one year, can administer the VEMMT.
- The VEMMT will allow OTs, practicing in early intervention, to identify, adapt and control the visual inputs that the infant constantly receives from the environment in order to enhance participation and performances for development in all aspects of life.
- The newly developed VEMMT can guide policy makers and government in decisions on investment on early child development. Most importantly, OTs will ultimately make a contribution by accruing information to add to the body of knowledge about the profession.
- It is apparent thus far that, the newly developed VEMMT can be used as an indicator of brain dysfunctions and aid for early intervention programmes. This VEMMT complements other developmental and medical assessments for the early identification and referral for treatment of neuro-developmental delays and impairments.

## **7.8 LIMITATIONS OF THE STUDY**

A first limitation of the study is associated with the COVID-19 pandemic. The COVID-19 pandemic has severely affected all humanity. From the COVID-19 pandemic's emergence in December 2019, the outbreak has influenced this study in different ways. With the permission of the scientific research committee the sampling method and size were adapted. The study sample for the pilot study could not be matched and was decreased. Due to the novelty nature of the pandemic, the researcher could no longer use the facilities of clinics or other health public spaces and special permission was obtained from the scientific research committee to conduct the pilot study at the researcher's private practice with adherence to the necessary covid regulations.

A second limitation is that of the possibility of selection biases. The researcher requested private clinics and known paediatricians to assist with the spread of invitational letters as parents were more likely to participate in the study that their paediatricians or general practitioners were familiar with. Participation behavior was also influenced by health of family members during the pandemic, such that parents with family members with health impairment cancelled their scheduled appointments.

Furthermore, the researcher experienced not only academic stress but also personal emotional stress due to the pandemic causing time delay for completion. Beyond addressing limitations, this study opens up a number of avenues for future research.

## **7.9 RECOMMENDATIONS**

The aims of the study with its objectives were achieved. The first step has been taken towards the development of the VEMMT and is showing promising results. The VEMMT will be useful in OT practices and/or for future research purposes.

Future plans further development of the VEMMT:

- The VEMMT should be administered by a certified rater who has attended a training course on the VEMMT and completed a specific number of independent measurements with approval results.
- Scientific evaluation will assist further development of the VEMMT by establishing intra-rater and inter-rater reliability. Intra-rater reliability will be achieved by calculating the consistency of scores of one rater across all measurable items with repeated use. Inter-rater reliability will be achieved by means of a measure of consistency used to evaluate the extent to which two or more judging participants agree in their assessment decision. An increase in the sample size will be required for statistical analysis between age ranges and gender to correlate the VEMMT with the standardised visual functional parameters. The larger the sample size will allow more information to be available and hence reduce certain uncertainties.
- Apply the VEMMT to infants at risk for the establishment of intervention principles and strategies with parental support.

- To link atypical VEMs to other neurological disorders and assessments.

## **7.10 CONCLUSION**

The newly developed Voluntary Eye Movement Measurement Tool is a goal-oriented measurement measuring voluntary eye movements during active participation in a natural setting. This tool has established content validity and can identify atypical development so that therapists can support infants with developmental difficulties, and their families. The newly developed Voluntary Eye Movement Measurement Tool is another milestone in the development of knowledge in the field of occupational therapy for functional vision.

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## APPENDICES

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# APPENDIX A



Faculty of Health Sciences

**Institution:** The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 18 March 2022 and Expires 18 March 2027.
- IORG #: IORG0001762 OMB No. 0990-0278 Approved for use through August 31, 2023.

## Faculty of Health Sciences Research Ethics Committee

15 June 2022

### Approval Certificate Annual Renewal

Dear Mrs CE Scholtz,

**Ethics Reference No.:** 614/2018 – Line 3

**Title:** DEVELOPMENT AND VALIDATION OF A CLINICAL MEASUREMENT TOOL FOR MEASURING VOLUNTARY EYE MOVEMENTS IN TYPICAL INFANTS SIX MONTHS OF AGE

The **Annual Renewal** as supported by documents received between 2022-05-18 and 2022-06-15 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on 2022-06-15 as resolved by its quorate meeting.

Please note the following about your ethics approval:

- Renewal of ethics approval is valid for 1 year, subsequent annual renewal will become due on 2023-06-15.
- Please remember to use your protocol number (614/2018) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

**Ethics approval is subject to the following:**

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

On behalf of the FHS REC, Dr R Sommers

MBChB, MMed (Int), MPharmMed, PhD

Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

*The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health)*

Research Ethics Committee  
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Fakulteit Gesondheidswetenskappe  
Lefapha la Ditsaense ea Maphelo

## APPENDIX B

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### **TITLE OF STUDY: DEVELOPMENT OF A CLINICAL MEASUREMENT TOOL FOR MEASURING VOLUNTARY EYE MOVEMENTS IN TYPICAL INFANTS SIX MONTHS OF AGE.**

Dear Parent/Primary Caregiver/Guardian

#### **INTRODUCTION**

I invite you to participate in a research study. This information leaflet will help you to decide if you want to participate. Before you agree to take part, you should fully understand what is involved. If you have any questions that this leaflet does not fully explain, please do not hesitate to ask me, the researcher, Christina Scholtz, Occupational Therapist. This study has received written approval from the Research Ethical Committee (REC) and the ethical clearance number is 614/2018.

#### **THE NATURE AND PURPOSE OF THIS STUDY**

The aim of the study is to develop a clinical measurement tool for measuring voluntary eye movements in typical six-month-old infants. You have been approached as a potential participant.

Your infant's age range is between six months to seven months.

Your infant was full term gestation with normal birth weight.

You do not have any concerns about your infant's development.

You as a parent/primary caregiver/guardian (PCG), is a very important source of information on how babies' eye movements develop. Your participation might be necessary for two phases.

#### **COVID PANDEMIC**

I, the researcher has received the vaccination. The researcher will carry the cost for testing herself and for you, the PCG, 72 hours before the appointment as the measurement cannot be completed with masks. The measurement will occur at my private practice.

Address: 41 Central Avenue, Flamwood, Klerksdorp.

No other person will be allowed in the rooms in this 72-hour testing period and before the scheduled appointment.

#### **STEP 1**

After you have done the COVID-19 test, you and your baby will come in for the first session where I will do a screening of your infant's visual functions and development. For the visual functions, your baby will be seated on your lap and I will present different cards to your baby to look at. This will take approximately 10 minutes. The first three cards measure your how clearly your baby can see up to about arm's length i.e. the visual acuity. The second three cards will measure how well your baby can see under different levels of contrast i.e. contrast sensitivity. The third measurement will measure the entire area that can be seen by your infant while focussing on a single point, the visual fields.

I will also give you a form to complete about your baby's development (the Ages and Stages questionnaire). Some tasks required by this questionnaire consist of handling objects. I have all the materials at my practice. The listed materials provided by the Ages and Stages manual are Cheerio's or other small food, mirror and small toys or toys easy to grasp. You are welcome to bring with your own food and toys from home. This step will take approximately 15 minutes.

### **RESULTS AND QUESTIONS**

After the questionnaire and measurements, I will give you immediate feedback on the results of the ASQ-3, visual acuity, contrast sensitivity and visual fields. If you have any concerns, and/or if the result from the measurements indicates that your infant's milestones may not be on track, I will provide you with a program and will follow up your infant without costs if necessary. If your infant's milestones are on track you are invited to participate with the second step of this study.

### **EXPLANATION OF PROCEDURES TO BE FOLLOWED FOR STEP 2**

This study involves observing your baby's eye movements during a play session using different toys. This step will take approximately 25 minutes. Your baby will be seated on your lap and I will present different harmless toys to the baby to look at. Reaching, grasping, holding and release will be observed.

The session will be video recorded to assist me to write out a description of how the baby looked at the toys. Because the session will be video recorded, I will protect your baby's identity by assigning a code/number to your baby. Your baby's name will never be used in the thesis or any other publication. The videos will be kept safe on my password protected computer and after submission of the thesis, it will be in safe keeping at the University of Pretoria for 15 years.

### **RISK AND DISCOMFORT INVOLVED**

There are no risks for both you and for your baby in taking part in this study. You can sooth your baby any time when needed during the breaks.

### **POSSIBLE BENEFITS OF THIS STUDY**

Although you will not benefit directly from the study, the results of the study will contribute meaningfully to the knowledge of typical development of infants. This session will help me to develop a measurement tool for voluntary eye movements in infants 6-to-7-months old. This measurement tool will be able to detect "at risk" infants for possible early intervention.

### **WHAT ARE YOUR RIGHTS AS A PARTICIPANT?**

Your participation in this study is entirely voluntary. You can refuse to participate or stop at any time during the study, interview and/or during the play activity without giving any reason. Your withdrawal will not affect you or your infant's treatment or access to any private or public medical institutions.

**COMPENSATION**

No compensation will be given for your participation.

**CONFIDENTIALITY**

All information that you give will be kept strictly confidential. The video will only be used for this research project. Research reports and articles in scientific journals will not include any information that may identify you or your baby. Your infant will be given a number and I will only use those numbers to refer to him/her.

Contact detail of researcher: CE Scholtz: 018-4686095 / 083 293 1956

Contact details of REC Secretariat: 012-356 3084 / 012-356 3085

Contact details of study leaders:

Prof CJE Uys: 082 493 2014 [kitty.uys@up.ac.za](mailto:kitty.uys@up.ac.za)

Prof R Hansraj: [HANSRAJR@ukzn.ac.za](mailto:HANSRAJR@ukzn.ac.za)

## APPENDIX B

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### **TITEL VAN STUDIE: ONTWIKKELING VAN 'N KLINIESE METINGSINSTRUMENT VIR DIE METING VAN WILLEKEURIGE OGBEWEGINGS BY TIPIESE BABAS SES MAANDE OUD.**

Geagte Ouer / Primêre Versorger / Voog

#### **INLEIDING**

Ek nooi u uit om aan 'n studie deel te neem. Hierdie inligtingsblad sal u help om te besluit of u wil deelneem. Voordat jy instem om deel te neem, moet jy ten volle verstaan wat daarby betrokke is. As u enige vrae het wat hierdie pamflet nie ten volle verduidelik nie, moet asseblief nie huiwer om my te vra nie, die navorser, Christina Scholtz, Arbeidsterapeut. Hierdie studie het skriftelike goedkeuring van die Navorsings etiese Komitee (REC) ontvang en die etiese klaringsnommer is 614/2018.

#### **DIE AARD EN DOEL VAN DIE STUDIE**

Die doel van die studie is om 'n kliniese metingsinstrument te ontwikkel om willekeurige ogbewegings in tipiese ses maande oue babas te meet. Jy is 'n potensiële deelnemer.

Die ouderdomsbeperking van u baba is tussen ses maande en sewe maande.

U baba was voltydse swangerskap met normale geboortegewig.

U is nie bekommerd oor die ontwikkeling van u baba nie.

U as ouer / primêre versorger / voog (PCG), is 'n baie belangrike bron van inligting oor hoe babas se ogbewegings ontwikkel. U deelname kan nodig wees vir twee stappe.

#### **COVID-PANDEMIE**

Ek, die navorser het die inenting ontvang. Die navorser sal die koste dra om haarself en vir u, die PCG, 72 uur voor die afspraak te toets, aangesien die meting nie met maskers voltooi kan word nie. Die meting sal by my privaat praktyk plaasvind.

Adres: Central laan 41, Flamwood, Klerksdorp.

Geen ander persoon sal in hierdie 72-uur-toetstydperk en voor die geskeduleerde afspraak in die kamers toegelaat word nie.

#### **STAP 1**

Nadat u die COVID-19-toets gedoen het, sal u en u baba inkom vir die eerste sessie waar ek 'n sifting van u baba se visuele funksies en ontwikkeling sal doen. Vir die visuele funksies sal u baba op u skoot sit en ek sal verskillende kaarte aan u baba voorlê om na te kyk. Dit sal ongeveer 10 minute duur. Die eerste drie kaarte meet u hoe duidelik u baba tot ongeveer die lengte van die arm kan sien, d.w.s. die visuele skerpte. Die tweede drie kaarte sal meet hoe goed u baba onder verskillende vlakke van kontras kan sien, d.w.s. kontras sensitiwiteit. Die derde meting meet die hele gebied wat deur u baba gesien kan word, terwyl u op 'n enkele punt, die visuele velde, fokus.

Ek sal u ook 'n vorm gee om te voltooi oor die ontwikkeling van u baba (die vraelys vir ouderdomme en stadiums). Sommige take wat deur hierdie vraelys vereis word, bestaan uit die hantering van voorwerpe. Ek het al die materiaal in my praktyk. Die genoteerde materiaal wat deur die Ages and Stages handleiding is Cheerio's of ander klein kos, spieël en klein speelgoed of speelgoed maklik om te begryp. Jy is welkom om jou eie kos en speelgoed van die huis af saam te bring. Hierdie stap duur ongeveer 15 minute.

### **RESULTATE EN VRAE**

Na die vraelys en metings, sal ek u onmiddellike terugvoer gee oor die resultate van die ASQ-3, visuele skerpte, kontrasgevoeligheid en visuele velde. As u enige bekommernisse het, en / of as die resultaat van die metings aandui dat u baba se mylpale nie op koers is nie, sal ek u 'n program gee en u baba sonder koste opvolg indien nodig. As u baba se mylpale op koers is, word u uitgenooi om deel te neem aan die tweede stap van hierdie studie.

### **VERDUIDELIKING VAN PROSEDURES WAT VIR STAP 2 GEVOLG MOET WORD**

Hierdie studie behels die waarneming van u baba se oogbewegings tydens 'n speelsessie met behulp van verskillende speelgoed. Hierdie fase duur ongeveer 25 minute. U baba sal op u skoot sit en ek sal verskillende onskadelike speelgoed aan die baba bied om na te kyk uitstrek, hou en vrylating sal waargeneem word.

Die sessie sal video opgeneem word om my te help om 'n beskrywing uit te skryf van hoe die baba na die speelgoed gekyk het. Omdat die sessie video opgeneem sal word, sal ek die identiteit van u baba beskerm deur 'n kode / nommer aan u baba toe te ken. U baba se naam sal nooit in die tesis of enige ander publikasie gebruik word nie. Die video's sal veilig gehou word op my wagwoordbeskermdre rekenaar en na die indiening van die tesis sal dit vir 15 jaar veilig by die Universiteit van Pretoria wees.

### **RISIKO EN ONGEMAK BETROKKE**

Daar is geen risiko's vir u en u baba om aan hierdie studie deel te neem nie. U kan u baba enige tyd kalmeer wanneer dit nodig is tydens die pouses.

### **MOONTLIKE VOORDELE VAN HIERDIE STUDIE**

Alhoewel u nie direk by die studie sal baat vind nie, sal die resultate van die studie betekenisvol bydra tot die kennis van tipiese ontwikkeling van babas. Hierdie sessie sal my help om 'n metingsinstrument vir willekeurige oogbewegings by babas van 6-tot-7 maande oud te ontwikkel. Hierdie metingsinstrument sal babas wat agterstande toon in tipiese ontwikkeling kan identifiseer vir verdere opvolg, verwysing en of intervensie.

### **WAT IS JOU REGTE AS DEELNEMER?**

U deelname aan hierdie studie is heeltemal vrywillig. U kan weier om te eniger tyd tydens die studie, onderhoud en / of tydens die speelaktiwiteit deel te neem of te stop sonder om enige rede te gee. U onttrekking sal nie u of u baba se behandeling of toegang tot enige private of openbare mediese instellings beïnvloed nie.

**VERGOEDING**

Geen vergoeding sal vir jou deelname gegee word nie.

**VERTROULIKHEID**

Alle inligting wat u gee, sal streng vertroulik gehou word. Die video sal slegs vir hierdie navorsingsprojek gebruik word. Navorsingsverslae en artikels in wetenskaplike joernale sal geen inligting bevat wat u of u baba kan identifiseer nie. U baba sal 'n nommer kry en ek sal slegs die nommers gebruik om na hom / haar te verwys.

Kontakbesonderhede:

Navorser: CE Scholtz: 018-4686095 / 083 293 1956

REC Sekretariaat: 012-356 3084 / 012-356 3085

Studie leiers:

Prof CJE Uys: 082 493 2014 [kitty.uys@up.ac.za](mailto:kitty.uys@up.ac.za)

Prof R Hansraj: [HANSRAJR@ukzn.ac.za](mailto:HANSRAJR@ukzn.ac.za)

## APPENDIX B

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### **SHLOOHO SA THUTO: NTSETSOPELE YA TEKANYO THULOSI BAKENG SA HO METHA KA BOITHAOPHO METSAMAO YA MAHLO E TLOAELEHILENG HO MASEA A KGWEDI DITSHELETSENG.**

Ho Motsoadi/ Mohlokamedi ya ke Sehlohong/ Mohlokamedi ya Seteheng

#### **SELELEKELA**

Ke le memela ho nka kapolo thutong ya di patlisiso. Tlhalisoleseding ena etla hothusa ho kgetha ho nka karolo. Pele o dumela ho nka karolo, o tshwanetse ho otlwisisa kameho ka botlalo. Haeba o na le dipotso ho se pampitshena ena esa sehlahosang, ka kopo seke wa geagea ho mpotsa, nna moqolotsi, Christina Scholtz, Mosebetsi mo phekodi. Boithuto bona bo amohetsoe ka mongolo hotswa ho Mogolotsi ho tsa boitsoaso komiti (REC) ha mmoho le boitsoase hlakisetso nomoro ke 614/2018.

#### **TLHATO LE MORERO TSA THUTO ENA**

Sepheo sa thuto ena ke ho ntshetso pele ya tleniki tekanyetso thulosi ho lekanya boithaopo metsamao ya mahlo etloa elehileng lo masea a kwedi tse tshelletseng. O kgethilwe o a tameditsoe joalo ka ona le bokwani ba morypeluoa.

Mecutafuta ya masea e mahateng a kgwedi tse tshelletseng ho isa kgwedding tse supileng.

Lesea la hao leng le nako etletseng ya boimana le etloaelehleng ya tswalo le boima.

Mao na kameho efe kapa efe ka ntshetso pele ya lesea la hao.

Wena joalo ka motswadi mohlokamedi ya ka sehlooheng (PCG) mohlodi hlahiso leseding wa bohlokoa wa motsa mao ya mahlo a lesea lentshetshopele. Mo kenya letsoho ha hao ho kaba le bohlokoa ka mekhahlelo emmedi.

#### **SEWA SESEHOLO SA COVID**

Nna joalo ka mogolotsi ke amohetse ente. Mogolotsi otlala nke boikarebelo ba ho lekola yena hammoho le wena, PCG ya hona tse mashome a supileng a metso emmeli 72 pele ho kopano le tekanyo ephethiloeng ntebe le maske. Tekanyetso eo etla etsahala boitloaetsong ba lekunutu.

Aterese: 41 Central Avenue, Flamwood, Klerksdorp.

Ha hona motho le a le meng ya dumeletsweng, ho ka kena ka phapuseng di noreng tse mashome a supileng a metso emmeli e ka nako ya hlahlobo le pele no nako ehlophisi tsoeng ya kopano.

#### **MOHATOWA PELE**

Ka mosao ho etsa diteko tsa Covid-19, wena le lesea la hao le tla boela letla hotla ho kopano ya ho gala moo ketlo tlaetsa lesea la hao tlhatlhobo ya tshebetso ya pono, le ntshetso pele. Ka thebetso ya pono ngwana kapo lesea la hao otlala le hara hodima hao ebe ke tla hlatusa hara hodima hao ebe ke tla hlatusa ho yena dikarata ka hofane ho ngwana a tle a dishebe. Hoomo ho ka nka metsotso ekabang eleshomo (10 minutes). Ka dikesata tse tharo tsa pele di lekanyetsa ko hohlaka hore ngwana wa hao akakgona hobona ho ka lekanya bolelele ba sephake homo ho bolela tebo ya pono.

Kerata tse tharo tsa bobedi di ka lekanyetsa ho bona hore na lesea la hao le ka kgone kapo lena kgonahalo ya hobona tlase boemo, kapo maemo a fapaneng khahlenong le kutloelo bohloko. Tekanyo ya borero e lekanya ka betlalo sebaka se ka bonoang ke lesea la hao le tsepamisitse makutlo ho lehalokone kapo ntlha elengwe ya sebeke sa pono.

Ke tla ho neya foromo ho etlatsa mabapi le pono ye lesea la hao le ntshe tsopele ya lona (dilemo le lethathamo a dipotso). Emeng ya mesebetsi ehlokahalang ya le thathamo la dipotso ke ya ho tshwara ntho. Ke na le thepa yohle ehlokaolong tshebeletsang ea ka. Lethathama la thepa efanang hoyu ka dilemo hammesho le sethala le tataiso, kapo dijo tse nyane seipone le dibapadiswa tse nyana kapo dibapadiswa le bonelo no ditshwara. O amohelehile ho tla le dijo tse hao, le di Bapadiswa hotswa lapeng. Mohato ona oka nka metsotso e leshome le metso e mehlano (15 minutes).

### **DIPHETOS LE SIPOTSO**

Ka marao ho le thathamo la dipotso le tekanyo, Etlare hang-hang ke ope makutso ho sephetso sa ASQ-3, tebo ya pono, kutloele bohloko le lebla la pona. Ma otshwenyehile le/kapo haebo sephetho hotswa tekanyong dibontsha ketsahalo ea bohlokoa di kekeng tsa ba motsheng was lesea, ke tla fana ka lenaneho le tshwanetseng ka esale morao ba lesea la hao ntle le ditjeho. Ma ketsahalo ya bohlokoa ye lesea la hao ele motsheng o motle, o amohelehile ho nka karola mohatong wa bobedi wa ethuto.

### **TLHALOSO EA MOKUSA ELATOANG YA MOHATSO WA BEBEDI**

Thuto ena e emeheng ho shebella motsa mao wa leihlo la lesea ka nako ya kanoloya papadi o sebedisa dibapadiswa ke hofana. Mohato one o kenka hoo e ka bang metsotso e meshome amabedi o metso e mehlomo. Ngwana wa hao otedule ka ho otloloha hodime hao, ke tla hlahisa di bapadiswa tse senang bokotsi tse fapaneng ho ngoena ho di lebeltho di sheba, ho di fihlella, ho di tshoara, ho di kuka le ho di lesa di tla hlokomeloa.

Kopanong ena hotla nkiwa video elehore etle etsebe ho nthusa ha ke ngola tlhaloso ka notlala ya hose ngwana one a no le tshebo ejoang no dibapadisoa, hobane kopano etla hatiswa ka mokgwa wa video. Ke tla sireletsa boitsebiso ba ngwana wa hao ka ho abela khoutu kapo nomoso ngwaneng wa hao. Lebitso la ngwana hao lekeke la sebediswa mo theseseng kapo phatlalatsong. Video eo etlabokoa tlhokomelong komporong yaka ka lentswe-kunutu le ka tlhahiso ya thesese. Etlaba bewa polokelang ko University of Pretoria dilemo tse leshome le mekso emehlamo.

### **HO AMEHA KOTSI LE BOEMO BOSA THABISENG**

Ho homa bo kotsi no wena le lesea la hao mo nka narolo thutong ena. O ka thudisa ngwana wa hao nako engwe le engwe ya ha wokahala ka nako ya kopano.

### **KAONAHALO LE MELEMO YA THUTHO ENA**

Leha okekeng wa bona molemo ka ho otloloha hotswa thuto ena, ditholwana tsa thuto di tla kenya lesoho ho utlwahala tsebong ntshetso pele etloaelehileng ya lesea. Kopano ena eka nthusa ho ntshetse ya dithuluso/disebedisoa no baithaopi ba motsamao wa leihlo ho lesea la kgwedi tse tsheletseng (6 months). Tekanyetso di sebediswa ena eka thusa ho lemoha kotsi ho kene dipakeng ho lesea ho sa le hotsha.

### **KE DIFENG BITOKELO TSA MONKA KAROLO?**

Monke karolo hahao ho thuto ena ke boithaupi. O ka hana honka karolo kapo ho tlohele hang-hang ka nako ya thuto puisano le/ kapo ka nako ya papedi ntle le hofana mabaka. Ho kgutlela morao/hotlomele hahao ho keke hoa ama wena kapophekoloealesea kapo phihlello ho lekunuteung kapo setheong sa bongaka sa setshaba.

### **MATSHEDISO**

Ha hona matswediso a hotla fanwa ka owa kapo otlafuwa ka nako ya nonke kerolo.

### **LEKUNUTU**

Tlhahiso leseding yohle otlafuwa ka yona etlaba lekunutu. Video eo etla sebediswa menenong ya dipatlisiso. Ditlaleho ho di patlisiso le mesebetsi ya saensele dikoranteng ha di no kenyeletsa tlhahiso leseding etla hlahisa boitsebiso ba hao le ba lesea. Lesea le tla fuwa/fumana nomoto me ketla sebedisa nomoso tseo mabapi le yena.

Dinomoso tsa mohala tsa mokopotsi: CE Scholtz: 018-4686095 / 083 293 1956

Dinomosa tsa mohala tsa REC Bongodi: 012-3563084 / 012-3563085

Binimosa tsa mohala tsa Thuto Moetapele:

Prof CJE Uys: 082 493 2014 [kitty.uys@up.ac.za](mailto:kitty.uys@up.ac.za)

Prof R Hansraj: [HANSRAJR@ukzn.ac.za](mailto:HANSRAJR@ukzn.ac.za)

## APPENDIX C

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### **TITLE OF STUDY: DEVELOPMENT OF A CLINICAL MEASUREMENT TOOL FOR MEASURING VOLUNTARY EYE MOVEMENTS IN TYPICAL INFANTS SIX-MONTHS-OF AGE.**

#### **Consent to participate in research for the Parents/Caregiver/ Guardian.**

I confirm that the person asking my consent to take part in this study has told me about nature, process, risks, discomforts and benefits of the study.

I have also received, read and understood the information leaflet regarding the study. I am aware that the results of the study, including personal details and video recordings, will be anonymously processed into research reports.

I have had time to ask questions and have no objection to participate in the study. I understand that there is no penalty should I wish to discontinue with the study or refuse to participate or decide to terminate/withdraw from the participation at any time.

I understand that the information obtained will only be used for research purposes and that it might be published in an accredited journal.

The research study has been verbally described to me. I understand what my involvement in the study means and I that I voluntary agree to participate and give my consent with my signature below.

\_\_\_\_\_  
Name of Parent/Caregiver/Guardian

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Researcher

\_\_\_\_\_  
Date

## APPENDIX C

---

### TITEL VAN STUDIE: ONTWIKKELING VAN 'N KLINIESE METINGSINSTRUMENT VIR DIE METING VAN WILLEKEURIGEE OOGBEWEGINGS BY TIPIESE BABAS SES MAANDE OUD.

#### Toestemming om deel te neem aan navorsing vir die Ouers / Versorger / Voog.

Ek bevestig dat die persoon wat my toestemming vra om aan hierdie studie deel te neem, my vertel het van die natuur, proses, risiko's, ongemak en voordele van die studie.

Ek het ook die inligtingsblad oor die studie ontvang, gelees en verstaan.  
Ek is bewus daarvan dat die resultate van die studie, insluitend persoonlike besonderhede en video-opnames, anoniem in navorsingsverslae verwerk sal word.

Ek het tyd gehad om vrae te vra en het geen beswaar om aan die studie deel te neem nie.  
Ek verstaan dat daar geen straf is indien ek met die studie wil staak of weier om deel te neem of te besluit om die deelname te eniger tyd te beëindig / te onttrek nie.

Ek verstaan dat die inligting wat verkry word slegs vir navorsingsdoeleindes gebruik sal word en dat dit in 'n geakkrediteerde joernaal gepubliseer kan word.

Die studie is mondelings aan my beskryf. Ek verstaan wat my betrokkenheid by die studie beteken en ek dat ek vrywillig instem om deel te neem en my toestemming te gee met my handtekening hieronder.

\_\_\_\_\_  
Naam van Ouers / Versorger / Voog

\_\_\_\_\_  
Handtekening

\_\_\_\_\_  
Handtekening

\_\_\_\_\_  
Datum

## APPENDIX C

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**SEHLOOHO SA THUTO: NTSHETSOPELE A TEKANYETSO THULOSE BAKENG SA HAO METHA KA BOITHAOPO METSAMAO YA MAHLO ETLOAELEHILENG HO MASEA A KGWEDI LE TSHELEKENG.**

**Tumello ho nkeng karolo ho fopotsa ya batswadi mohlokamedi ya ka sehlooheng/mohlokamedi**

Ke a tiisa motho ya kopang tumello ho nka karolo thuto ena ompolelletse ka tlhaha tshebetso, kotsi, ho selokolowe/pnotholohe le melemo ya thuto.

Ke amometse, ke badile ke utlwesititse thahiso le seding epampitsaweng mabapi le thuto.

Ke etse hlooka sephetho sa thuto ena, ntlhatsefeletse batho baka le video e hatisitswmg ka mekhoha eas tsejoeng esejetsoang dipatlisiso le ditlaleo. Ke bile le nako ea ho botsa dipitso ka seke kaba le likhayetso ho nkeng karolo thutsong ena.

Ke utlwesisa hore ha hona kotla haeba le lakatsa ho tlonela kapohose tswelle pele ka dithutso, kapok e hana ho nka kanolo ho etsa geto ya ho kgaola/ ho kgutle la omrao ho nkeng kanolo hang-hang.

Ke utlwisisa hore tlhahiso leseding mereno efumanoang etla sebediswe feela ho mereno lipatli sisi le ka hlahiso e amohetsoe ke di konoata.

Bipatlisiso tsa thuto di hlahositswa ka botlalo ho nna. Ke utlwisisa ho nka kanola thuto ena ho bolelang ke dumetse boithaopong ho nka karolo.

Kef ana ka tumelawo ka ho Tekena ka tlase:

\_\_\_\_\_  
Lebitso la motswadi/Mohlolomed

\_\_\_\_\_  
Tekeno

\_\_\_\_\_  
Mofopotsi

\_\_\_\_\_  
Lehla/Letsats

# APPENDIX D

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**TITLE OF STUDY: DEVELOPMENT OF A CLINICAL MEASUREMENT TOOL FOR MEASURING VOLUNTARY EYE MOVEMENTS IN TYPICAL INFANTS SIX-MONTHS-OF AGE.**

**Verbal informed consent**

I, the researcher had read and fully explained the information leaflet to the Parent/Caregiver/Guardian whom I had asked to participate in the study.

The participant indicated that s/he understood that the results of the study, including personal details regarding the interview will be anonymously processed into a research report. Also, that the video recordings were for the research data and would not be shared to a third party.

The participant indicated that s/he had time to ask questions and had no objection to participate in the research. S/he understood that there was no penalty should s/he wished to discontinue with the study.

I hereby certify that the client had agreed to participate in this study.

\_\_\_\_\_  
**Researcher**

\_\_\_\_\_  
**Signature**

\_\_\_\_\_  
**Date**

## APPENDIX D

---

**TITEL VAN STUDIE: ONTWIKKELING VAN 'N KLINIESE METINGSINSTRUMENT VIR DIE METING VAN WILLEKEURIGE OOGBEWEGINGS BY TIPIESE BABAS SES MAANDE OUD.**

### **Mondelinge ingeligte toestemming**

Ek, die navorser het die inligtingsblad gelees en volledig verduidelik aan die Ouer / Versorger / Voog wat ek gevra het om aan die studie deel te neem.

Die deelnemer het aangedui dat sy/hy verstaan dat die resultate van die studie, insluitend persoonlike besonderhede rakende die onderhoud, anoniem in 'n navorsingsverslag verwerk sal word. Ook dat die video-opnames vir die navorsingsdata was en nie aan 'n derde party gedeel sou word nie.

Die deelnemer het aangedui dat sy/hy tyd gehad het om vrae te vra en geen beswaar gehad het om aan die navorsing deel te neem nie. Sy/hy het verstaan dat daar geen straf was nie, moes sy/hy wou staak met die studie.

Ek sertifiseer hiermee dat die kliënt ingestem het om aan hierdie studie deel te neem.

\_\_\_\_\_  
**Navorsers**

\_\_\_\_\_  
**Hantekening**

\_\_\_\_\_  
**Datum**

## APPENDIX D

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**SHLOOHO SA THUTO: NTSETSOPELE YA TEKANYO THULOSI BAKENG SA HO METHA KA BOITHAOPO METSAMAO YA MAHLO E TLOAELEHILENG HO MASEA A KGWEDI DITSHELETSENG.**

**Tumellano e tsebisitsoeng kamalomo**

Nna, mogolotsi ke badile le ho hlalosa ka botlalo/ hahiso leseding pampitshaneng ho moswadi/ Mohlokamedi ya ka sehlohong/ le mohlokamedi bao ke ba kupilentg ho nka karolo thuto ena.

Banka karolo/ monka karolo o bontshitse hore eena o utlwisitse sephetho sa thuto ho kenyeletsa ntlha tse feletseng tsa bootho baka mabapi le puisano ka mokhoa osa tsejoeng osebetsoa ka ho fopotsa ha tlaleho le ka video ehatistsweng ka bofopotsi me bokeke ba anolelonoa ho motho wa bosaro. Monkakanolo o botshitse hore eeng ona le nako e oho botsa dipotso me hawa khanyetso honking karolo ka mofoposoa. Eena o utlwisitse hone ha hona dikotlo gobello ha ebaneng a ka lakatsa ho kgaotsa kapo ho kgutlela mosao ka di thuto.

Ke mona ka tiisetso ya home motshehetsi o dumelang ho nkeng kanolo thuto ene.

\_\_\_\_\_  
**Mogolotsi**

\_\_\_\_\_  
**Tekena**

\_\_\_\_\_  
**Letsatsi/lehla**

# APPENDIX E

---

## **DEVELOPMENT AND OF A CLINICAL MEASUREMENT TOOL FOR MEASURING VOLUNTARY EYE MOVEMENTS IN TYPICAL INFANTS SIX MONTHS OF AGE.**

Dear colleague,

I would like to invite you to consider being part of an expert review panel to evaluate the content validity of a measurement tool. The development of the measurement tool is for my PhD degree in occupational therapy at the university of Pretoria, South-Africa. I am very aware of your busy schedule, but your input would be greatly appreciated.

### **Background of the newly developed voluntary eye movement measurement tool (VEMMT)**

Most existing tests of vision related functioning are designed for adults. For infants at risk, the situation is different. Loss of vision in the adult is fundamentally different from lack of visual processing from an early age. Infants cannot verbalize their symptoms and do not follow instructions. A better picture of functional vision has to be obtained for six-month-old infants by using a valid clinical measurement tool for eye movements. With this tool, a history of typical sensory-motor behaviour to identify systems influencing the neuronal networking for higher cognitive functioning, thoughts, ideas and occupational participation is obtained.

A team-based approach is also necessary and requires a common framework of thinking. This clinical measurement tool can support infants with developmental difficulties and their families, provide a mechanistic understanding of disorders, help define prognoses, document the effects of interventions and estimating the national prevalence of developmental delays in the visual-perception and action systems.

### **Aim**

The aim of the study is to develop and validate a clinical measurement tool for measuring voluntary eye movements in typical six-month-old infants.

### **Formulation of objectives**

The following objectives were identified to reach the aim of the study:

- To identify, define and analyse the construct of voluntary eye movements in typical six-months-old infants
- To develop, and construct the Voluntary Eye Movement Measurement Tool (VEMMT)
- To establish content validity; and
- To pilot the newly developed VEMMT.

### **Significance of the VEMMT**

The newly developed and validated VEMMT for infants six months of age will assist the clinician in an early intervention clinical setting. Therefore, the key outcome of this research is to develop and validate a measurement tool that can be used in a clinical setting to identify deviations in eye movements that require further investigation and/or early therapeutic intervention options to benefit infants as a class, enhancing neuroplasticity. This will also help to inform policy makers and government in their decision on investment on early child development. Most importantly, occupational therapists will ultimately make a contribution by accruing information to add to the body of knowledge about the profession.

### **Expectations of your participation**

Your voluntary participation in this study will provide useful information on this topic.

You will receive the following:

- the VEMMT manual (Appendix F)
- administration and scoring criteria (Appendix G)
- scoring form (Appendix H)
- validity scoring form to be completed (Appendix J)

Please send the completed validity scoring form to [hayjuba@lantic.net](mailto:hayjuba@lantic.net).

It would be appreciated if it would be completed by \_\_\_\_\_ 2021/2.

Thank you for your assistance.

Sincerely

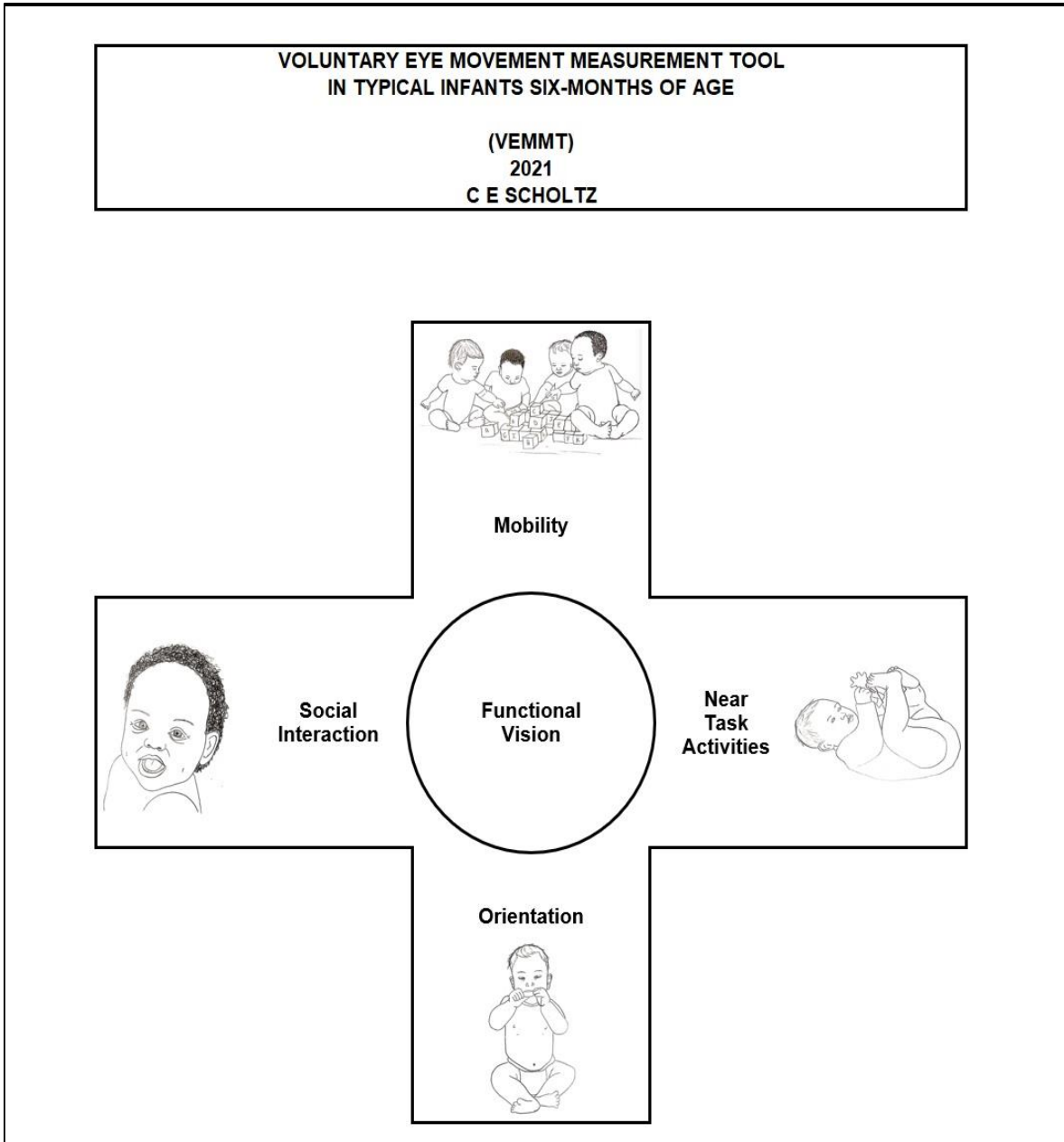
Christa Scholtz

PhD student in Occupational Therapist

**Supervisor: Prof. K Uys (Department Occupational Therapy, UP)**

**Co-supervisor: Prof. R. Hansraj (Department Optometry, UKZN).**

**APPENDIX F**  
**ADMINISTRATION USER MANUAL**  
Voluntary Eye Movement Measurement Tool  
(VEMMT)



Voluntary Eye Movement Measurement Tool  
(VEMMT)

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## **1. Overview**

The Voluntary Eye Movement Measurement Tool (VEMMT) is a clinical measurement tool, measuring functional vision. Functional vision describes how infants do function in vision-related activities that involve multiple parameters based on response characteristics. Functional vision is distinct from visual function. Visual function for example visual acuity (VA) and contrast sensitivity (CS) describes various parameters of how the eye and visual system function in terms of threshold performances and are tested one at a time. To be included in the study infants from the age six months day one up to six months day 30/31 days underwent an examination based on typical development in VA, CS and perceptual-motor-social development (Ages and stages Questionnaire). VEMMT is a comprehensive measurement of gaze shifting and holding with the related sub-domains and items.

The VEMMT is based on the researcher's PhD thesis and 40 years of clinical experience. Voluntary eye movements for 6-month-old infants are the foundation to process functional visual information efficiently for perception and cognition, memory, organized purposeful actions, and attention on an ever-changing environment in all cultures & for all ages, to promote communication/social interaction, near task activities and mobility/orientation.

## **2. User qualifications**

This VEMMT was developed for occupational therapists and other healthcare professionals working in the early intervention field, with knowledge and clinical experience of atypical development in infants in the first year of life. It is highly recommended to practice this measurement tool on five typical infants between 6 months 1 day and 6 months 30/31 days before utilizing it on atypical infants or infants at risk.

### 3. Suggested administration procedures

Before using the VEMMT it is important that you familiarize yourself with the manual.

#### 3.1. Computing the infant's chronological age

Infants born between 37- 40 weeks are considered as full term and their chronological age can be computed by:

Subtracting the infant's date of birth from the evaluation date.

*Please note: When borrowing days from months always borrow 30 days regardless of the month. When borrowing months from years always borrow 12 months.*

#### **Take note: For full term infants**

The age range must be between 6 months 1 day and 6 months 30/31 days to continue with this measurement. If the infant is younger or older, this measurement tool will not be applicable.

#### 3.2. Premature infant's corrected age calculation

A premature infant born less than 37 weeks gestation is considered as premature infants, therefore, their corrected age is calculated as follows.

Corrected adjusted age: Subtracting the number of months and days the infant was born prematurely from the chronological age. The purpose of the calculation for premature infants is to ensure that the corrected adjusted age is between the range 6 month and 31/31 days.

#### **Take note: For Premature infants**

The age range must be between 6 months 1 day and 6 months 30/31 days to continue with this measurement. If the infant is younger or older this measurement tool will not be applicable.

#### **4. Guidelines for the administrator/examiner**

It is important that the VEMMT session is relaxed and keep your voice soft and friendly. Interactions between examiner and infant is important. The examiner should be familiar with the administration procedures and scoring criteria before administering the VEMMT. This will ensure the standardization of the use of objects, as well as how and where to present it. The test items should be administered exactly as described and the direction and verbal directions should be given as specified. The examiner should not wear any jewellery around the face, neck and hands. The shirt of the examiner needs to be plain (i.e., no patterns or images) and of a dark colour. You can wear your glasses, but your hair must be out of the face.

##### **4.1. The Parent/Caregiver/ Guardian participation**

The parent/caregiver/guardian (PCG) cannot be coached to assist in the administration of the VEMMT. Parent/caregiver/ guardian can in short sentence give confirmation to the infant such as good girl/ boy.

#### **5. Environment**

Typically, illumination from overhead diffuse fluorescent lights in the clinical setting is adequate. Natural light can assist if more light is required as long as the infant is not facing the light source. Shadows and uneven illumination must be avoided.

Avoid visual and auditory noisy surroundings. Consider the temperature of the room. An ideal room temperature for winter and summer is between 20 to 22 degrees Celsius.

### 6. Infant positioning

The PCG will hold the baby in a supportive sitting position; at the lower trunk on her/his lap with infant's pelvis at 90 degree for stability. The PCG is instructed not to cue the infant as to the location of the card, toy or object.

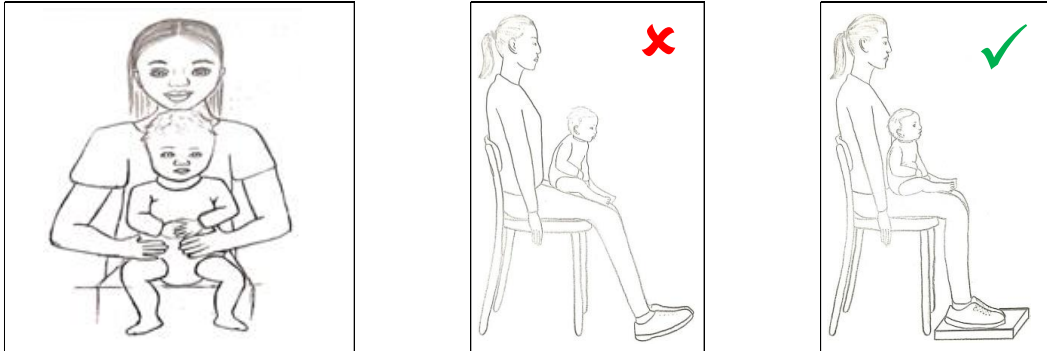


Figure F.1: Supportive sitting position on PCG's lap with pelvis in 90 degree for stability. Pelvis of infant is in 90 degree to prevent sliding down from PCG's lap. Support the feet of PCG, if necessary, to level the upper legs of the PCG with floor.

The upper limbs should be free to move for the reaching and grasping measurement. Position the infant, so he or she faces the tester in an optimal position for participation in the test situation. The height of the table needs to be in line with the centre of the infant's trunk. Figure F.2 illustrates the infant on the PCG's lap at the table.



Figure F.2: Sitting at table and the arms of the infant are free for reaching and grasping.

Positioning oneself in an optimal location for face-to-face communication, are perceived signals to be used for social interaction. Adjustable height chairs are therefore recommended. The examiner should position him/herself such that the infant's eyes is directly aligned with the examiner's eyes during social play activities.

**Take note**

During the administration of VEMMT, the examiner should not look at the face/ eyes or communicate to the person/caregiver holding the infant during the administration of an item unless specified differently for a test item.

**7. Regulatory state of infant**

In preparation for administration the infant needs to be in a quiet alert state. During the quiet alert state, infants may focus on visual or auditory stimuli with a bright look and without thrusting movements. No food can be given to the infant by the parent during the session. If the infant has a bowel movement, stop the administration process. The parent is allowed to clean the infant and then continue with the administration process.

**8. Ocular conditions**

All items will be scored under binocular viewing conditions.

**9. Head movement**

In designing the VEMMT it was decided not to instruct the caregiver to hold the infant's head but instead note any movement of the head. The reason for it, the VEMMT must be as close as possible to the spontaneous functional vision of an infant during the engagement of a typical social interaction and/or play with a toy. The positions of targets are placed in central vision for which no head turn is necessary. Head turn must occur beyond the 30 degree central vision. Head movement is expected when measuring peripheral vision and gaze pursuit.

**10. Dominance**

Infants at 6-months of age do not show any evident preferences with regard to the frequency of right- or left-sided reaching and grasping. It can be concluded that the frequency of the reaching and grasping behaviour will be equal to both sides for 6-month-old infants.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**11. Prompts given during administration**

Biological movements and ostensive signals activate different regions in the social brain during a social interaction. Table F.1 summarizes the ostensive signals. When and which prompts to be used are well described in the administration manual.

Table F.1: Summary of ostensive signals that will be used during the administration.

<b>Ostensive</b>	<p><u>Sound</u>: Voice calling, speech, laughter, coughing.</p> <p><u>Voice calling</u>: The infant hears a voice calling him/her. Call his/her name, have mutual eye contact for 3 s then proceed.</p>
<b>Visual</b>	Face to face interaction, direct gaze.
<b>Biological</b>	<p>Eye movement such as eyebrow raise, hand movements such as a gesture, mouth movement such as smile.</p> <p>For mutual gaze: Eyebrow raise with accompanying smile and direct gaze.</p>
<b>Non- Biological Motions</b>	Mechanical toys

**12. Breaks and termination**

Pacifiers can be given to the infant during breaktime. Breaktime indicators are set out in the manual. Inform and explain to the caregiver in advance what are expected from them during these breaktimes. Table F.2 is a summary of the breaktimes.

Table F.2: Breaktimes as stipulated in the administration manual.

<b>Breaktime between domains</b>	A breaktime between domains, sub-domains or sub-categories is to set up the equipment for the next measurement. This break allows the examiner time to set up for the next measurable item to be tested. This should not be longer than 30secs.
<b>Breaktime as specified in administration manual</b>	To assist the optimal performances of the infants, PCG can console their baby by speaking softly to her/him, bringing hands together, giving a gentle hug during breaktimes or if infant is under distress.
In the case of an infant with lusty crying for 90 s or more with regulatory disorders such as extreme fussiness, irritability and difficult to calm down by caregiver, the VEMMT needs to be stopped.	


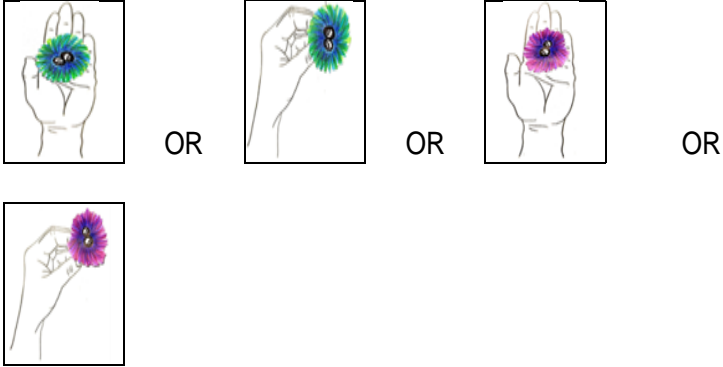
Voluntary Eye Movement Measurement Tool  
(VEMMT)

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**13. Distractors**

A distractor serves to shift an infant's attention and gaze away from the engaged target to allow the examiner to remove a toy from the infant or ask for the toy he/she is engaged with. The examiner can alternate the position, or the colour of the distractor as indicated in Table F.3. The distractor has to be out of reach of the infants.

Table F.3: Distractors: Infant holds an object in a hand, examiner presents a distractor.

The hand that holds the toy.	Examiner presents the distractor. Examiner can alternate the position and colour of a target.
Right	
Left	
Both hands	If infant holds toy with both hands the examiner can use any of the above.

**14. Test distance**

Different distances will be used and will be specified on the administration manual.

**15. The rating scales**

Each item is measured according to a specific criterion from zero (0) to two (2) which are visually defined in the manual. Table F.4 describes the criteria for the numerical values.

Table F.4: Rating scales:Criteria of the different rating scores.

Score	Quality of performance
<b>2</b>	<b>Efficiently:</b> Response immediate and consistent.
<b>1</b>	<b>Somewhat efficiently:</b> Delayed in response. Performed with difficulty. Slowly in response.
<b>0</b>	<b>Inefficient:</b> Unsuccessfully performed. Infant appears disorganised. Infant shows panic: discomfort and may cry.

INTERPRETATION OF THE RESULTS.	
<b>RATING SCORE 2: EFFICIENTLY</b>	<b>HAS REACHED THE EXPECTED TYPICAL OUTCOME</b>
A score 2 indicates that the infant appears to be doing well in that developmental domain.	
<b>RATING SCORE 1: SOMEWHAT EFFICIENT</b>	<b>A SCORE CLOSE TO THE EXPECTED TYPICAL OUTCOME</b>
A score of 1 indicates that and infant need occupational therapy with further monitoring.	
<b>RATING SCORE 0: INEFFICIENT</b>	<b>A SCORE BELOW TO THE EXPECTED TYPICAL OUTCOME</b>
A score of 0 indicates that the infant needs to be referred for further investigation and examinations.	

### 16. Scoring

The VEMMT consists of 21 items and is administered in about 20-25 min. Items 22-26 are observable behaviours for attention. The session is video recorded for scoring after the session. Items 8, 9 and 20 are scored immediately after the administration. Record the best response observed. An X will score the level that fits the best. The VEMMT is administered by filling out the score form (Appendix H) which is available in a word file. You may photocopy the scoring form. The video recording will assist the examiner to give the score which best describes how the infant uses the eye-hand movements in each measurable item corresponding to the criteria provided in the manual. Enter a score in the score column.

As different toys are used during play, social interaction and eye movements, attention can be observed and will be scored separately under the scoring section for attention. When scoring the different items for attention, it is helpful to keep in mind what sub-domain they belong to because then the examiner can relate the item to the key domain it is intended to evaluate.

The items are grouped and each will be assessed and scored separately except for the domain gaze holding with the sub-domain eye muscle balance in different directions. The eye position 1,6,4 and 5 will be scored during the vertical and horizontal smooth pursuit eye movement (SPEM) as illustrated in Figure F.3. The score will be noted on the recording sheet. A sum score is needed for the final score.

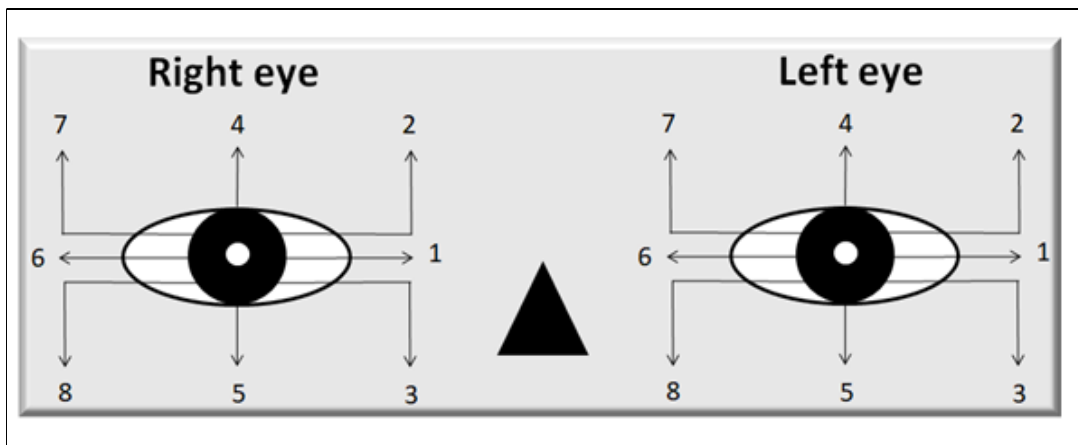


Figure F.3: The nine positions of the voluntary eye movement (VEM).

Voluntary Eye Movement Measurement Tool  
(VEMMT)

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**17. Baseline**

A baseline is necessary for the optimal performances of the infant during this measurement for optimal alertness and engagement. Prompts and baseline requirements are specified with each item. Table F.5 summarises the prerequisites for a baseline.

Table F.5: Baseline prerequisites

<b>Position</b>	The tester should not look at the eyes/face of the caregiver holding the infant or communicate with the caregiver during the measurement. Infant sits supported on the caregiver's lap.
<b>Equipment</b>	Make sure your equipment is set at the position, angles. The examiner needs to be familiar with the procedures.
<b>Quiet alert state</b>	In preparation for administration the infant must be in a quiet alert state. It is a state 4 with a bright look, focus on visual or auditory stimuli without thrusting movements.
<b>Attention getting</b>	The infant needs to disengage first i.e., he needs to let go with what he/she is busy with, get attention and eye contact to the examiner. This can be achieved by saying the name of the infant with a soft voice, eyebrow lifting and a smile (See Table F.1 for more examples). Example: Peter Hallo (Always the name first)! OR Tap under the desk and say again Peter Hallo!

**18. Timeline and test items/sessions**

The entire VEMMT should be administered in one sitting. The items are sequenced so that the infant experiences the same type of eye movements in several successive activities. The items in a particular sub-domain must be given together as a cluster. Should the infant express stranger anxiety during the administration the measurement need to be terminated. The infant will score a 0 for that particular domain. If the VEMMT is interrupted, items that remain in the other domains can be completed in a 2<sup>nd</sup> session within 24 hours of the 1<sup>st</sup>.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**19. Domains, sub-domains and items.**

The VEMMT are clustered in four domains, five sub-domains and 26 items. Table F.6 illustrates the domains, sub-domains and items.

Table F.6: The domains, sub-domains and items.

Domain	Sub-domain	Items
<b>A.Functional vision for participation</b>	<b>1.Near task work</b>	Look, reach, grasp, hold and release rattle with the right hand
		Look, reach, grasp, hold and release rattle with the left hand
		Looking, reaching, touching and holding a ball, with both hands to midline
		Adaptive reach with tactile input
	<b>2.Social interaction</b>	Peek a Boo
		Gaze Following (Left; Right)
<b>B.Gaze holding</b>		Muscle balance in nine directions
		Direct penlight reflection
		Ocular alignment cover/uncover (Right ;Left eye)
		Convergence
<b>C.Gaze shifting</b>	<b>3.Smooth pursuit eye movement (SPEM)</b>	Horizontal SPEM
		Vertical SPEM
		Circular clockwise SPEM
		Circular anti-clockwise SPEM
	<b>4.Gaze pursuit (GP)</b>	Gaze pursuit from infant's left to right
		Gaze pursuit from infants' right to left
	<b>5.Saccades</b>	Fixation shift paradigm (Left; Right; Above)
		Gap shift paradigm (Left; Right)
		Express saccades
		Pupillary response (Left/Right).
		Exogenous saccades/ blink response
<b>D.Attention</b>		Disengagement
		Attention holding
		Attention getting
		Joint attention
		Sustained attention and self-regulation

**20. THE VEMMT kit**

The kit is used for infants between 6 months 1 day and 6 months 30/31 days of age and contains a number of carefully suitable selected toys. The toys were selected based on previous studies and the researcher's clinical experience knowing what toys encourage eye movements in the young cerebral palsy (CP) child with cerebral visual impairment (CVI). They are also selected to make infants more interested to look at. During the measurement there will be enough opportunities to observe spontaneous eye movements for scoring joint and sustained attention as well as attention getting, holding and releasing.

**Take note**

The VEMMT kit includes small parts that can be dangerous for infants if placed in the mouth. Make use of the distractors to take the toys away before the infant puts into the mouth. Do not leave the infant and parent unattended. It is important to note that the toys and objects should not be used as materials for training the eye movements.

## 21. Recording the VEMMT

Figure F.4 illustrates the set up for non-stop videorecording.

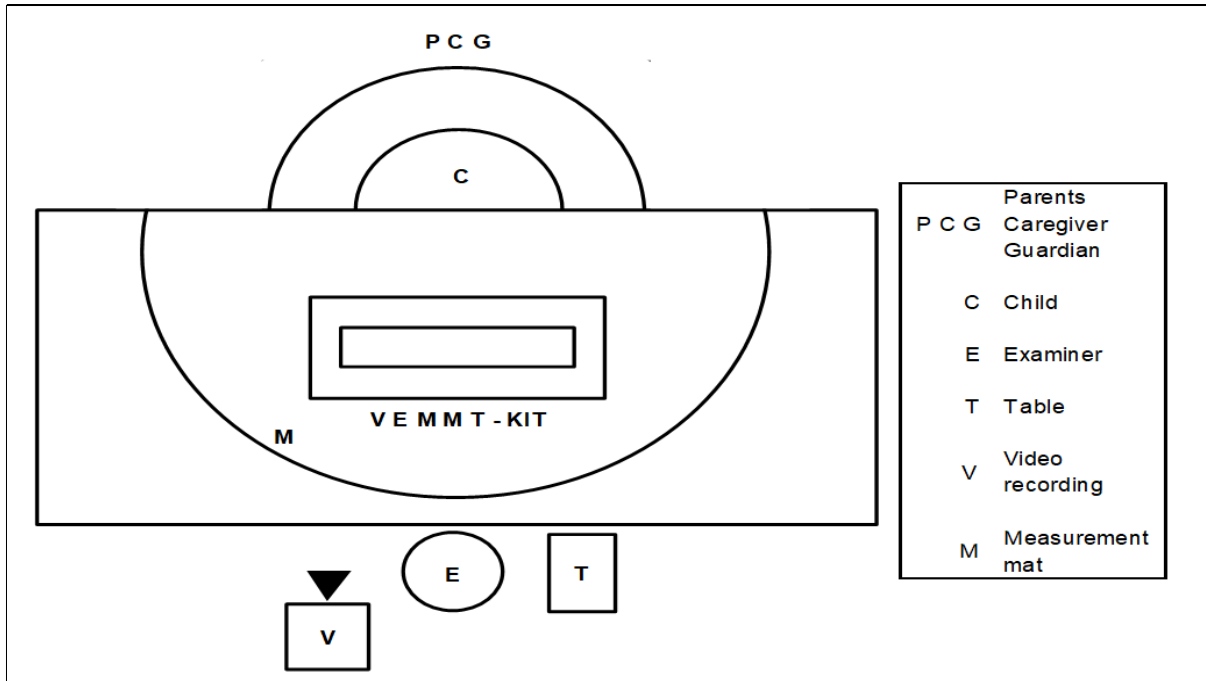


Figure F.4: Set up for the VEMMT recording

The sessions will be recorded on video in a standardised manner:

- The infant should sit on the PCG comfortably and being supported lightly on the lower trunk, in front of and close to the table. The examiner should sit on the opposite side.
- The standardised measurement mat must fit on table; therefore, not too deep and wide. The size of the table and the size of the mat must be well matched.
- If the examiner is right-handed the table will be on the right side for the toy placements and the camera should then be placed on the left side of the examiner higher at the head of the sitting examiner and slightly off midline of the examiner. This placement makes it possible to observe the eyes and hand movements of the infant. The camera and table will be placed opposite for left handers. The set-up must be done before the parent or caregiver enter the room. The recording will be slightly from the side and above.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

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- The toys and other testing material must be placed on the dominant side of the examiner on a lower table so it will not be visible to the infant.
- The PCG will be instructed not to cue the child as to the location of the card, toy, or object. Position the infant, so he or she faces the tester in an optimal position for participation in the test situation. The examiner should position her/him so that the infant's eyes is directly aligned with the examiner's eyes. Adjustable height chairs are therefore recommended. The tester should not look at the eyes/face of the person holding the infant during the test unless the PCG is soothing the infant during break times.

## 22. Placement and measurements

Figure F.5 illustrates the placements and measurements of the stimulus cards.

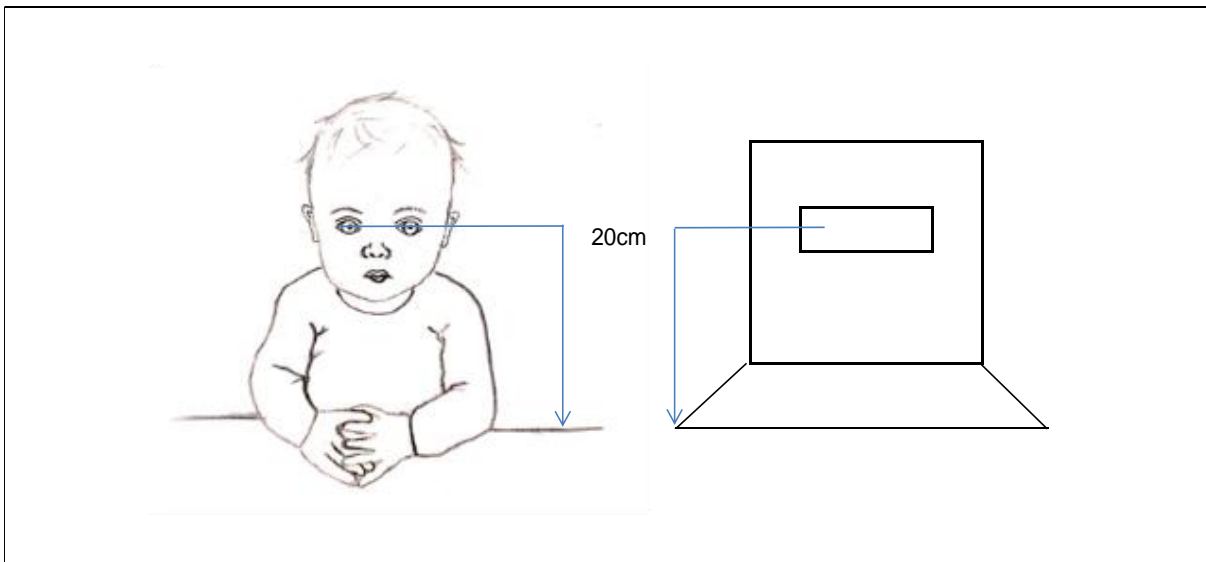


Figure F.5: The height of the centre of the slit for the stimulus cards.

The centre of the stimulus cards must be at the same level than the infant's eyes that are in a supportive sitting on the PCG's lap as illustrated in Figure F.5. The markers on the floor plan indicate the placements of the toys and is illustrated in F.6, F.7, F.8 and F.9 that is included in the testing kit.

## Voluntary Eye Movement Measurement Tool (VEMMT)

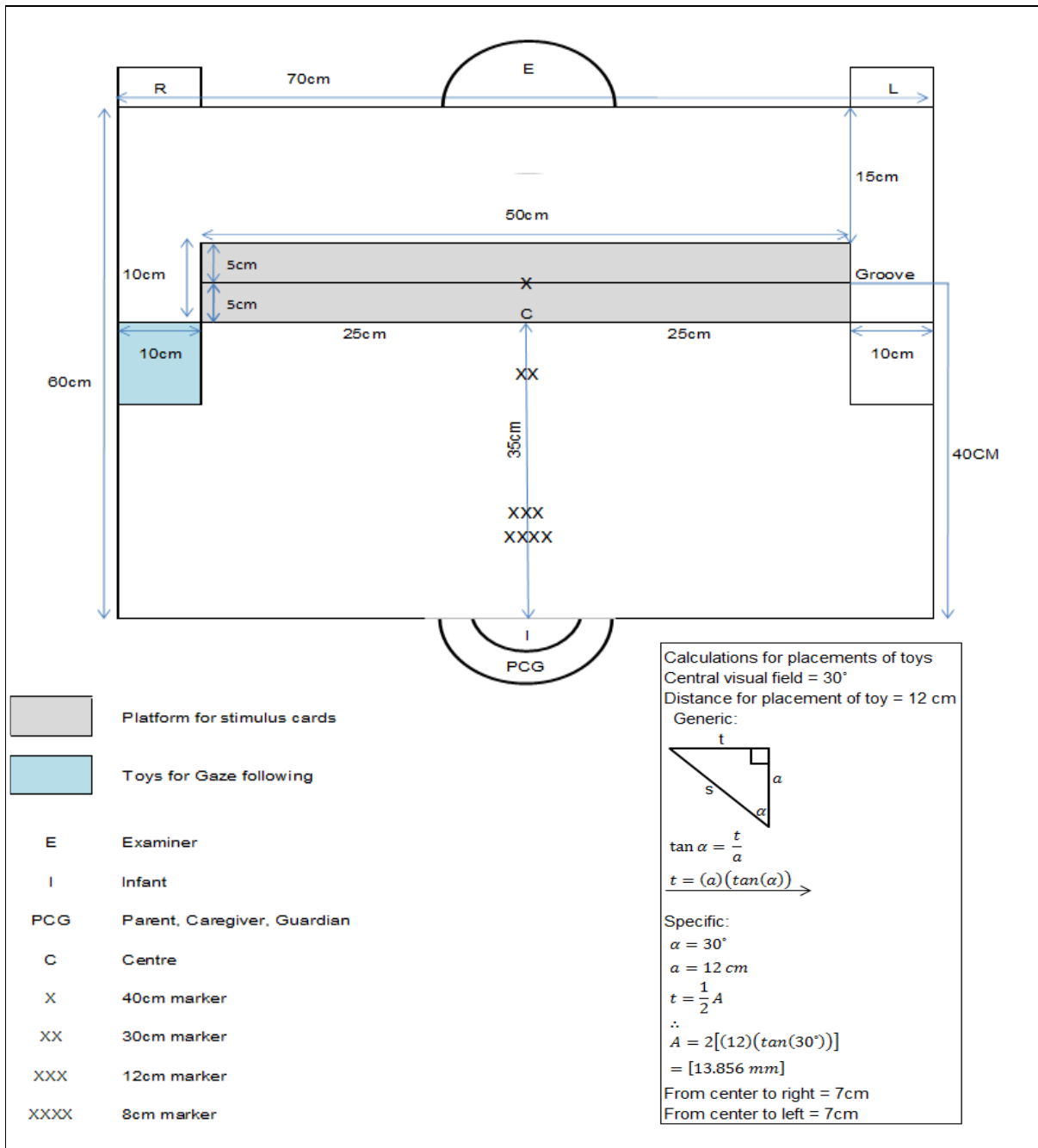


Figure F.6: Main floor plan included in the testing kit.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

Floor plan for the sub-domain looking, reaching, grasping, holding and releasing the rattle with the right/left hand is illustrated in Figure F.7.

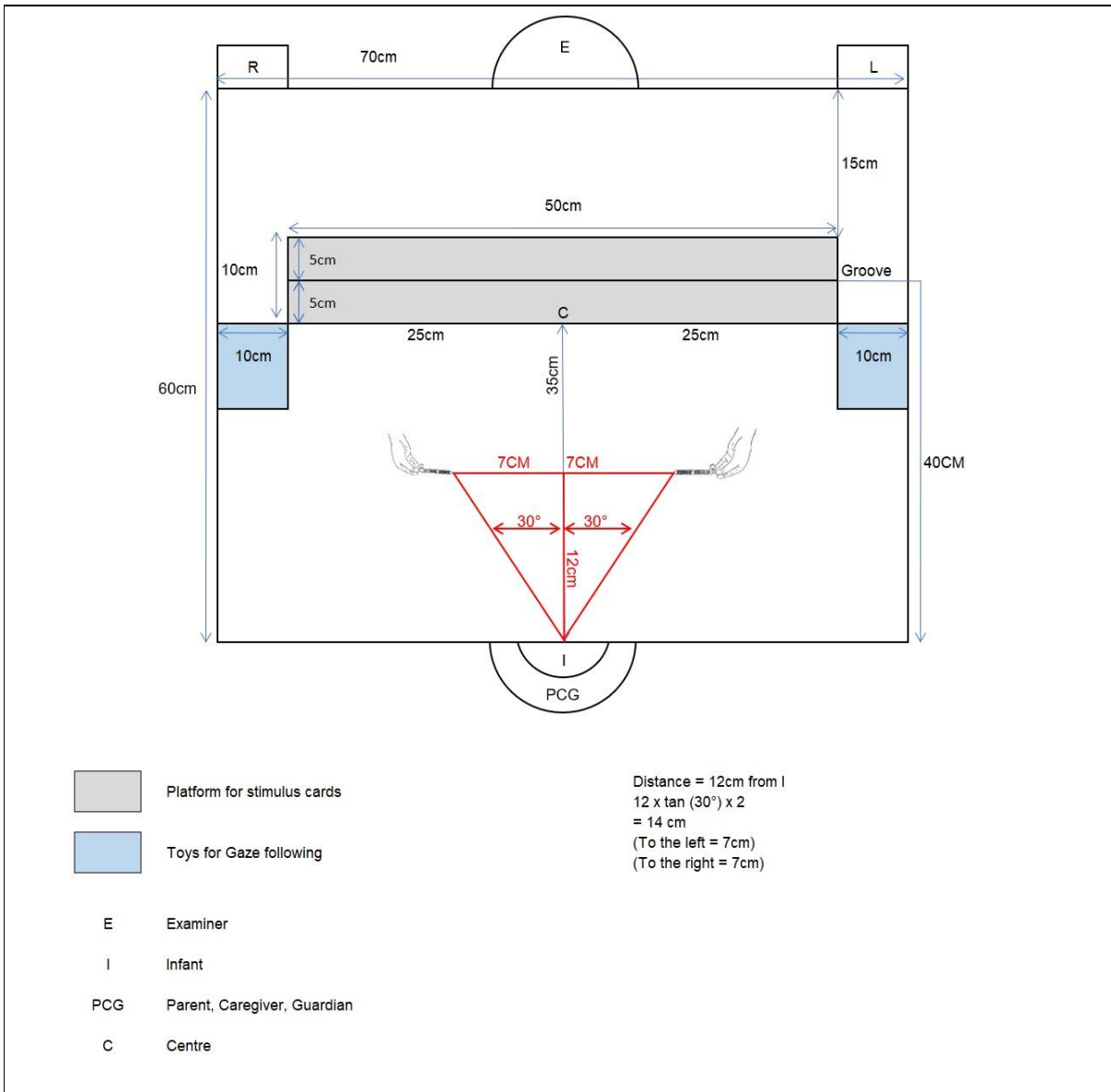


Figure F.7: Floor plan for the sub-domain. Looking, reaching, grasping, holding and and releasing the rattle with the right/left hand.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

Floor plan for the sub-domain looking, reaching, touching and holding a ball, with both hands to midline is illustrated in Figure F.8.

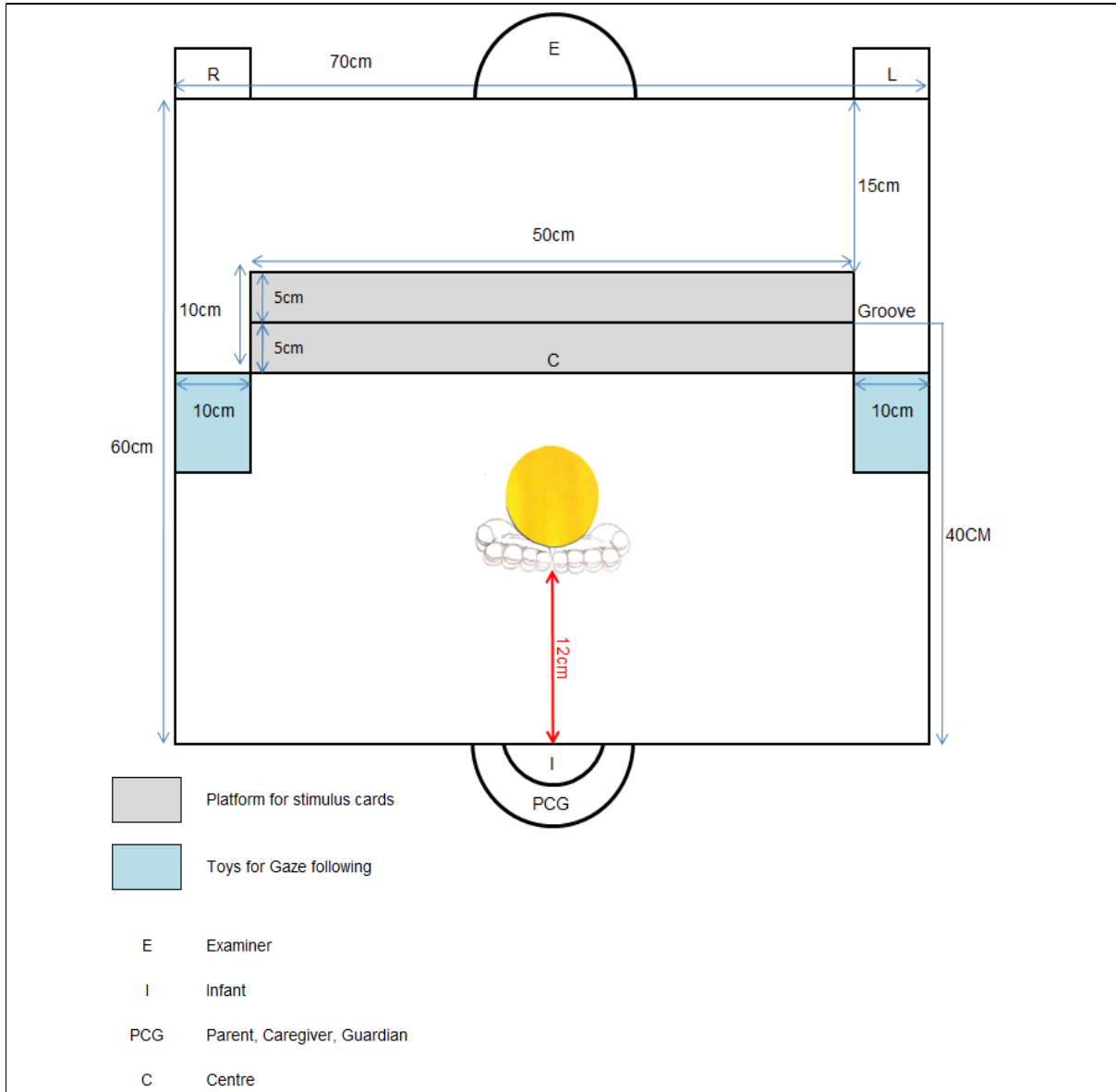


Figure F.8: Floor plan for the sub-domain: Looking, reaching, touching and holding a ball, with both hands to midline.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

Floor plan for the sub-domain gaze following is illustrated in Figure F.9.

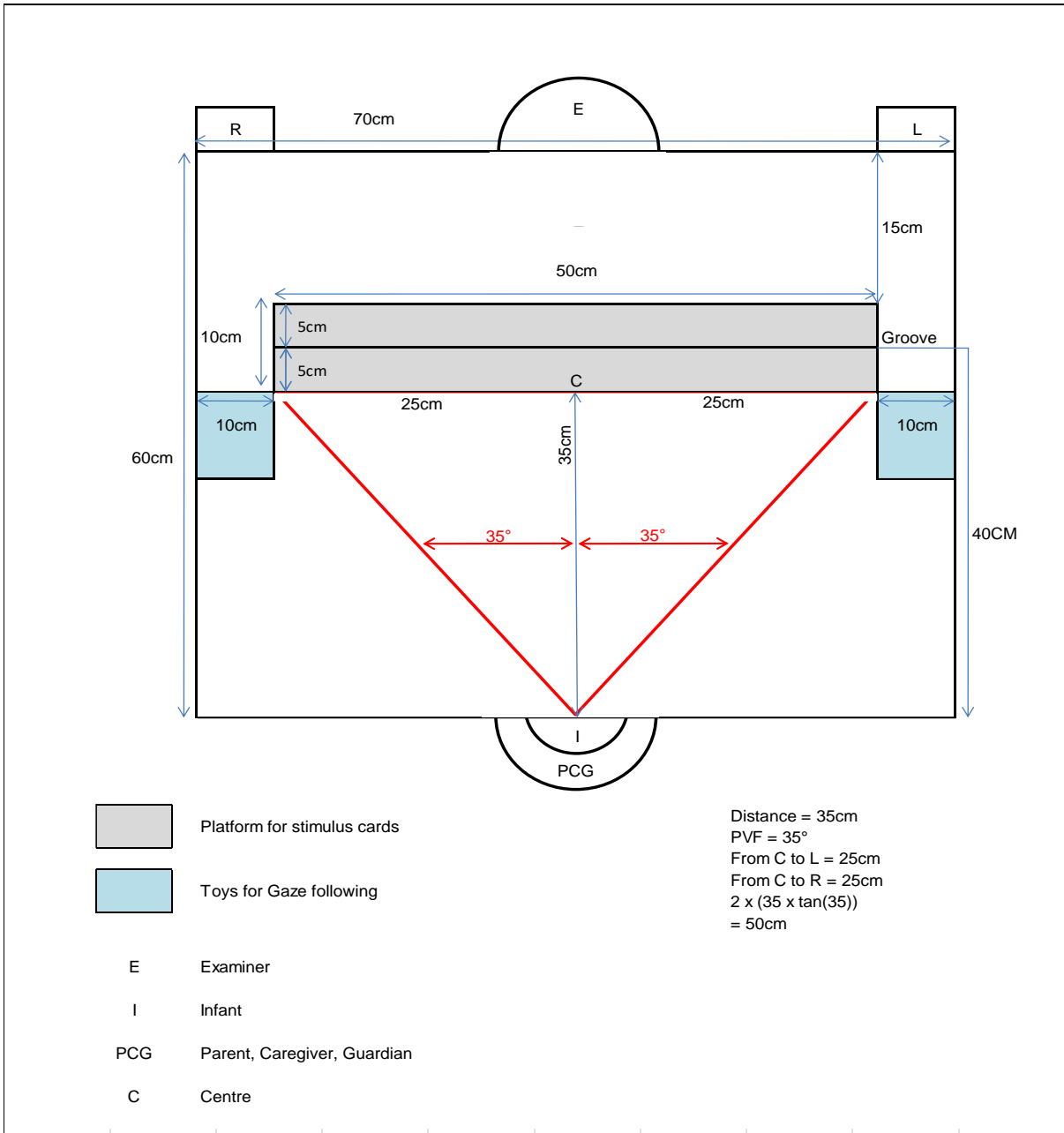


Figure F.9: Floor plan for the sub-domain gaze following.

### 23. Stimulus cards

Different stimulus cards were developed for the measurement of specific eye movements. These cards slide into a 2 cm groove for stability. All stimulus cards have the same height. Items that are measured in the central visual fields have the same width. For item 15 and 16 which measure gaze pursuit, the stimulus cards are wider as peripheral vision is needed for head turn. The stimulus cards have a specific measurement that will be placed in a platform groove and is illustrated in Figure F.10. The stimulus cards and its measurements are illustrated in Table F.7.

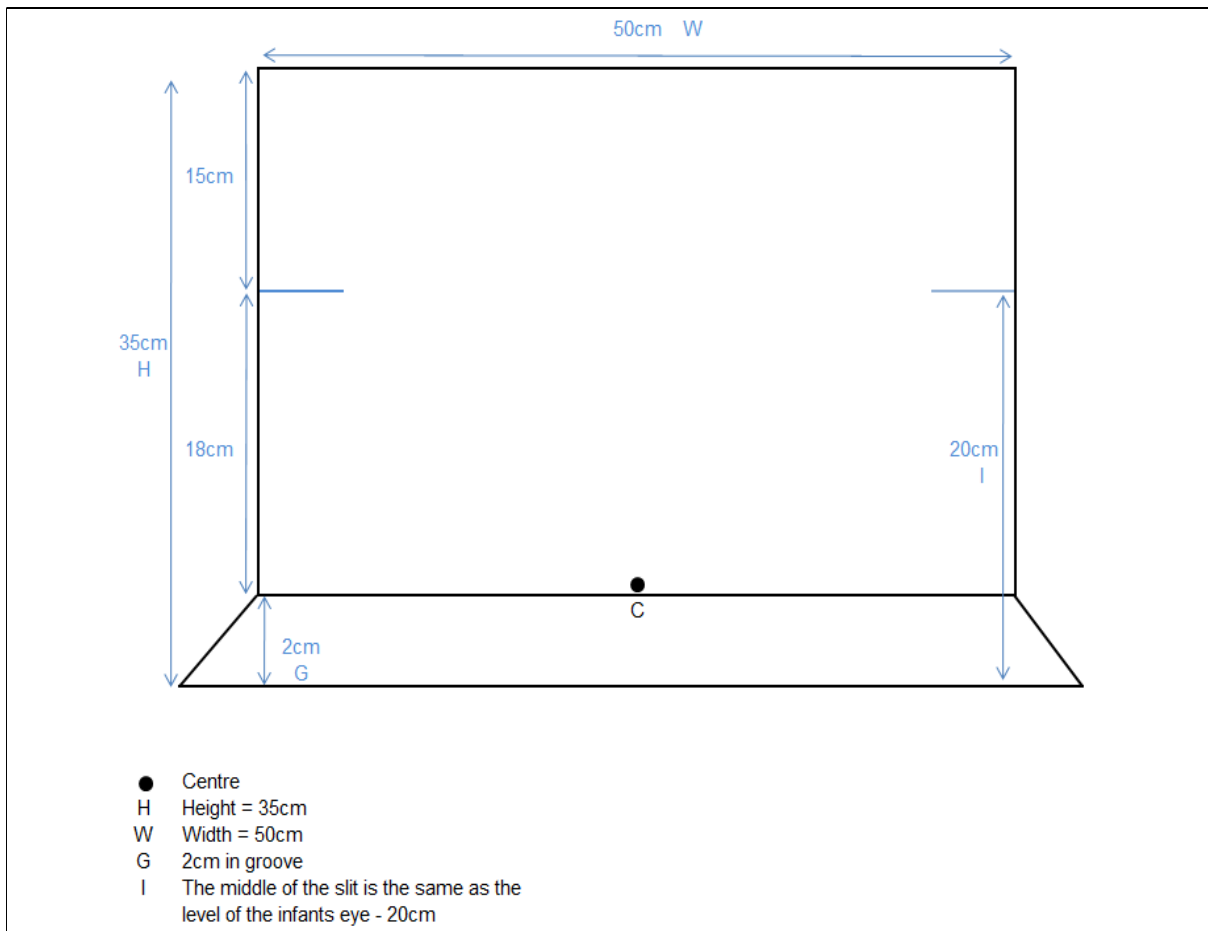
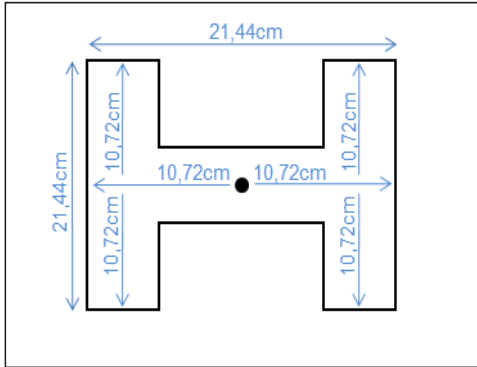
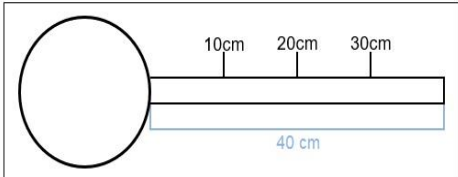
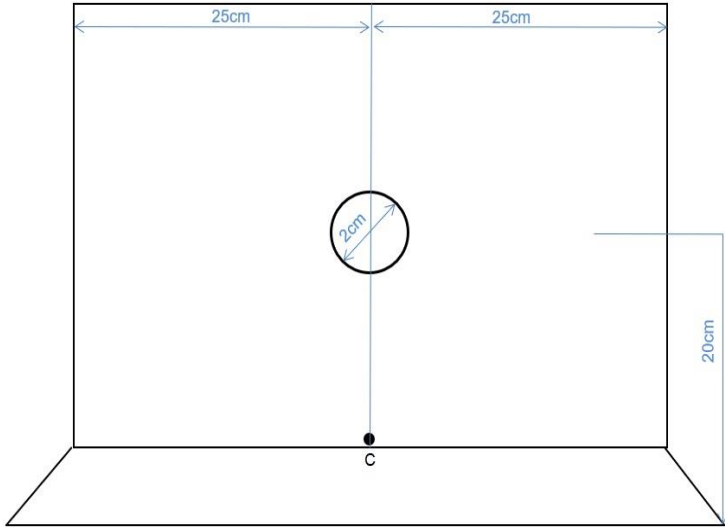


Figure F.10: Platform with the groove for stimulus cards.

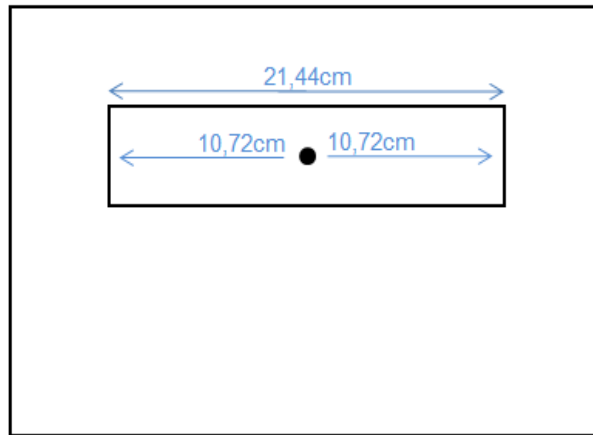
Voluntary Eye Movement Measurement Tool  
(VEMMT)

Table F.7: Measurements of stimulus cards

<p>Stimulus cards for muscle balance</p>	<div style="text-align: center;">  </div> <p>Size of the slit: <math>40 \text{ cm} \times \tan(15^\circ) \times 2 = 21.44 \text{ cm}</math>.                  From Center &gt; L = 10.72 cm                  From Center &gt; R = 10.72 cm</p>
<p>Convergence stimulus stick</p>	<div style="text-align: center;">  </div>
<p>Convergence stimulus card</p>	<div style="text-align: center;">  </div>

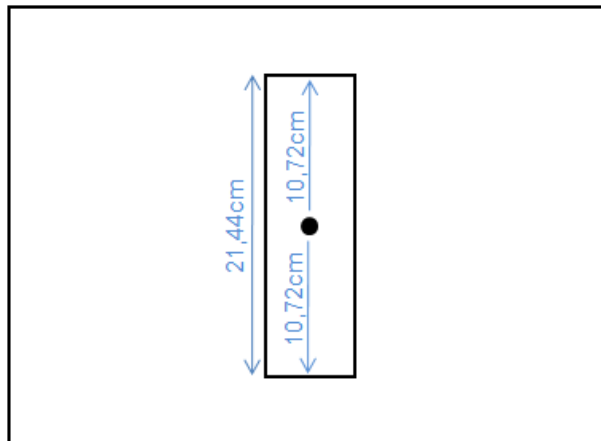
Voluntary Eye Movement Measurement Tool  
(VEMMT)

Horizontal SPEM



Distance 40 cm in central visual field of 15°.  
 Size of the slit:  $40 \times \tan(15^\circ) \times 2 = 21.44$  cm.  
 From Center > L = 10.72 cm  
 From Center > R = 10.72 cm

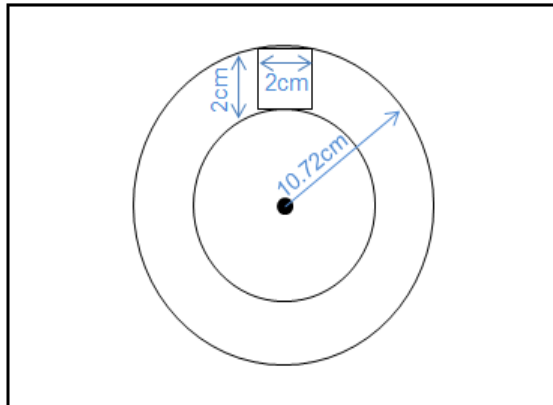
Vertical SPEM



Distance 40 cm in central visual field.  
 Size of the slit:  $40 \times \tan(15^\circ) \times 2 = 21.44$  cm.  
 From Center > L = 10.72 cm  
 From Center > R = 10.72 cm

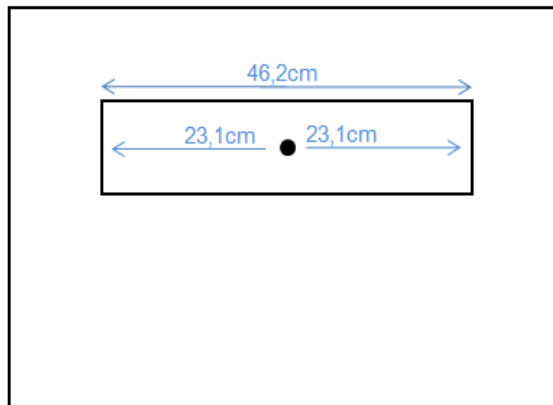
Voluntary Eye Movement Measurement Tool  
(VEMMT)

Circular SPEM



Distance 40 cm in central visual field.  
 Size of the slit:  $40 \times \tan(15^\circ) \times 2 = 21.44$  cm.  
 From Center > L = 10.72 cm  
 From Center > R = 10.72 cm

Gaze pursuit



Distance 40 cm from infant and starting and end point at  $30^\circ$   
 Opening of slit =  $40 \times \tan(30^\circ) \times 2$   
 = 46.2 cm  
 From the Centre to L = 23.1 cm  
 From the Centre to R = 23.1 cm

Voluntary Eye Movement Measurement Tool  
(VEMMT)

<p>Fixation shift paradigm</p>	
<p>Gap shift paradigm</p>	
<p>Express saccades</p>	

**24. Toys in the VEMMT box**

The toys chosen are to elicit specific eye-hand actions. Very specific instructions will guide the examiner on how, where, when to present the toy with the outcome as expected. The platform will be used to place the stimulus cards vertical and to limit background noise. Figure F.11 illustrates the VEMMT box with toys with the platform.

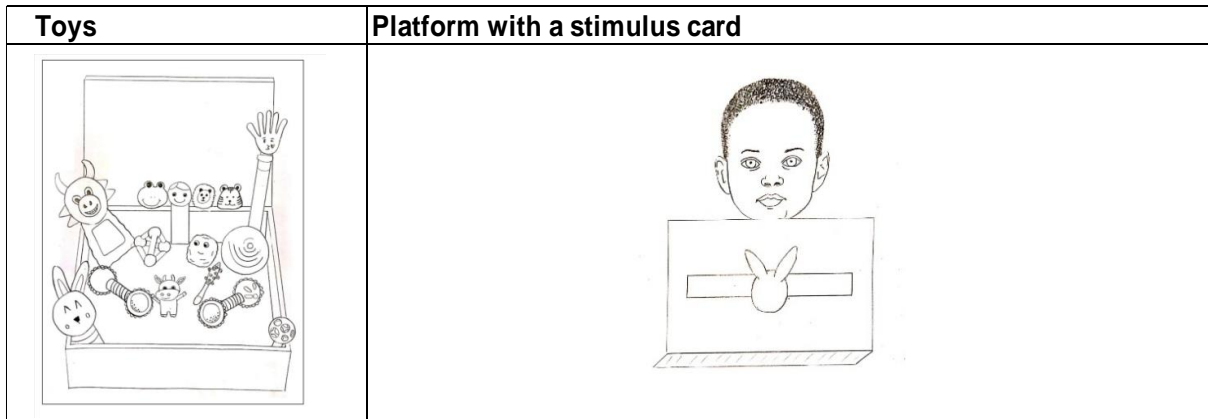


Figure F.11: Toys and the platform with a stimulus card

Voluntary Eye Movement Measurement Tool  
(VEMMT)



**25. Preferential looking: Warm-up game**

Preferential looking is based on the infant's preference for colour, objects, contrast, contours, faces, direction and speed of the movement of targets and against a patterned/plain; a moveable /non-moveable background.

The main advantage of using the preferential looking paradigm in the clinical practice, reaction to gaze holding, and shifting are that they can be calculated and that it does not require infants to verbalise their symptoms as they also do not follow instructions. To familiarize the infant with the targets and procedures to follow, play a hide and seek game.

Tap on the back of the stimulus card until the infant focuses and use verbal prompt. As infant fixates on the board, a rabbit appears above and in the center of the board. Wiggle the rabbit for 5secs and use second verbal prompt. Take the toy away and repeat the procedure for the left and right side as seen in Figure F.12.

Verbal Prompt: "Peter, (name calling first) where is the rabbit?"  
"Peter, (name calling first) Hallo! Hallo!"

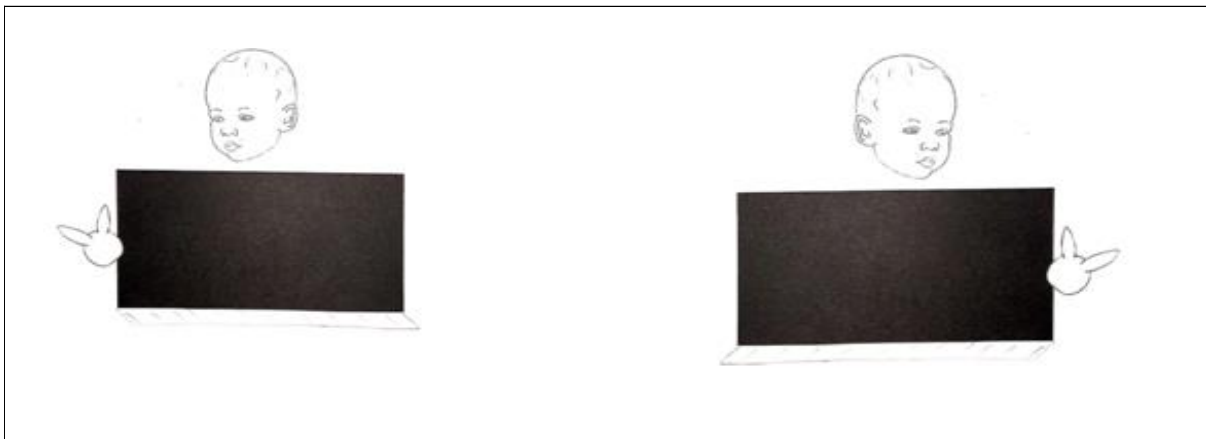


Figure F.12: Warm-up preferential looking toy rabbit game.

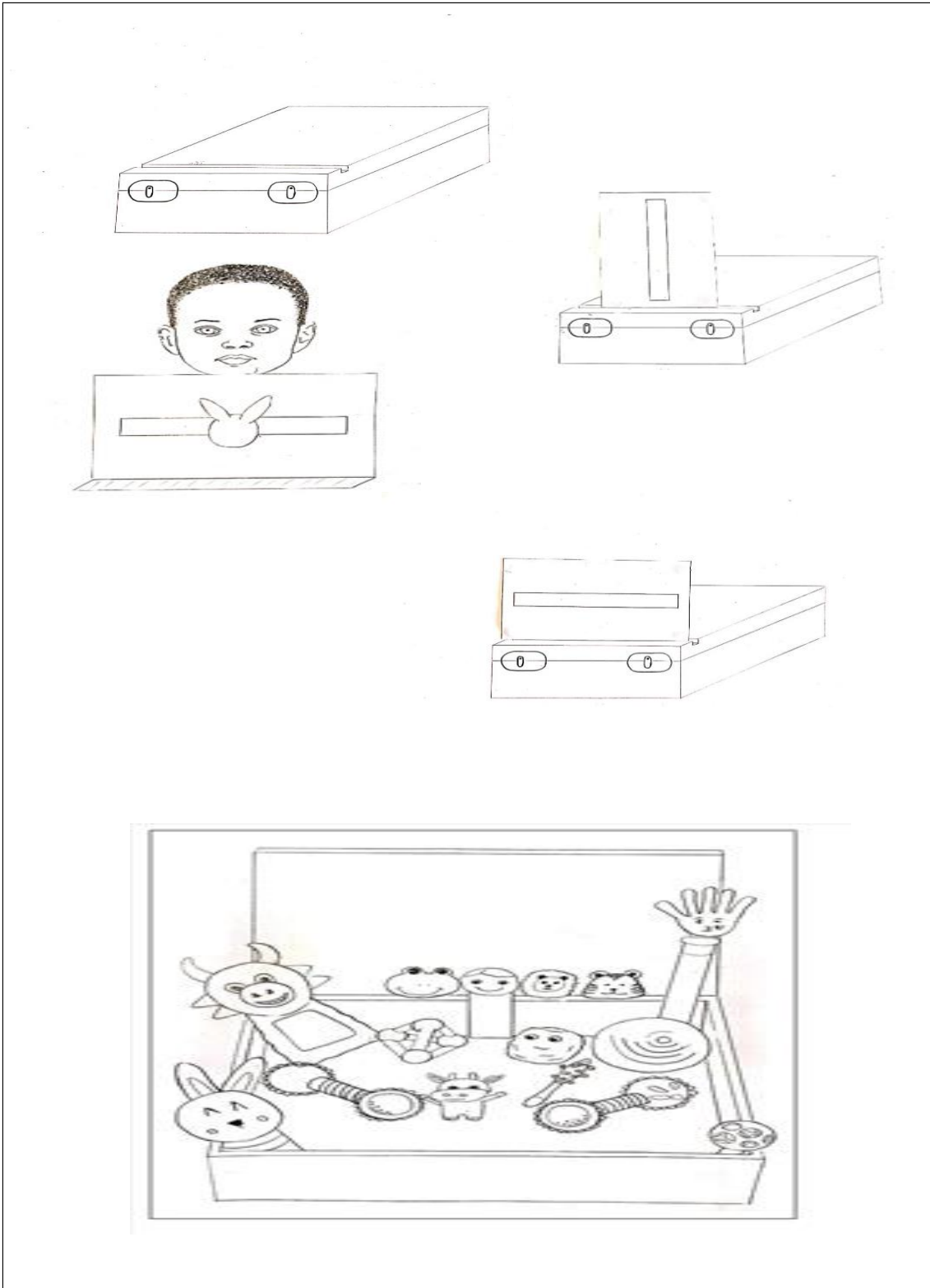
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**APPENDIX G**  
**ADMINISTRATION AND SCORING**



**Table G1: DOMAINS AND ITEMS**

	Items	Distance	Field	Target
<b>A. Functional vision for participation</b>	1. Look, reach, grasp, hold and release rattle with the right hand	12 cm	PVF	Rattle 12 cm
	2. Look, reach, grasp, hold and release rattle with the left hand	12 cm	PVF	Rattle 12 cm
	3. Looking, reaching, touching and holding a ball, with both hands to midline	12 cm	CVF	Yellow ball 13 cm diameter
	4. Adaptive reach with tactile input	Infant's hand	CVF	6.5 cm masking tape with red dot, 1,5 cm in middle
<b>Social interaction</b>	5. Peek a Boo	60 cm	CVF	Examiner's hand and face
	6. Gaze Following	35 cm	PVF	Attractive cars H12 cm, L14 cm, W10 cm
<b>B. Gaze holding</b>	7. Muscle balance in different directions	40 cm	CVF	Faces 4,5 cm diameter
	8. Direct penlight reflection	30 cm	CVF	Penlight
	9. Ocular alignment cover/uncover	30 cm	CVF	Penlight
	10. Convergence	40 cm	CVF	Puppet 6 cm in diameter
<b>C. Gaze shift</b>	11. Horizontal SPEM	40 cm	CVF	Puppet 8 cm
	<b>Smooth pursuit eye movement (SPEM)</b>			
	12. Vertical SPEM	40 cm	CVF	Puppet 8 cm
	13. Circular clockwise SPEM	40 cm	CVF	Puppet 8 cm
	14. Circular anti-clockwise SPEM	40 cm	CVF	Puppet 8 cm
<b>Gaze shift</b>	15. Gaze pursuit from infant's left to right	40 cm	PVF	Puppet 12 cm
<b>Gaze pursuit (GP)</b>	16. Gaze pursuit from infants' right to left	40 cm	PVF	Puppet 12 cm
<b>Gaze shift Saccades</b>	17. Fixation shift paradigm	40 cm	CVF	Cards with stripes, 13 cm x 13 cm with a red dot, 3 cm in middle
	18. Gap shift paradigm	40 cm	CVF	Light and target 3 cm
	19. Express saccades	40 cm	CVF	Light different colour caps
	20. Pupillary response	8 cm	CVF	Light
	21. Exogenous saccades/ blink response	40 cm	CVF	Examiner's hand
<b>D. Attention</b>	22. Disengagement			
	23. Attention holding			
	24. Attention getting			
	25. Joint attention			
	26. Sustained attention and self-regulation			

CVF: Central visual field (OU= 30 degrees)  
 PVF: Peripheral visual field (OU= beyond 30 degrees)  
 OU: Both eyes  
 VP: Verbal prompt  
 NVP: Non-verbal prompt  
 S: Start  
 C: Center  
 E: End

**Rating Scale**

Each item is measured according to a specific criterion from zero (0) to two (2) which are visually defined in the manual as illustrated in Table G.2. The interpretation of the results is illustrated in Table G.3.

Table G.2: Rating scales: Criteria of the different rating scores.

Rating Scale	
Score	Quality of performance
<b>2</b>	<b>Efficiently:</b> Response immediate and consistent.
<b>1</b>	<b>Somewhat efficiently:</b> Delayed in response. Performed with difficulty. Slowly in response.
<b>0</b>	<b>Inefficient:</b> Unsuccessfully performed. Infant appears disorganised. Infant shows panic: discomfort and may cry.

Table G.3: Interpretation of results.

INTERPRETATION OF THE RESULTS.	
<b>RATING SCORE 2: EFFICIENTLY</b>	<b>HAS REACHED THE EXPECTED TYPICAL OUTCOME</b>
A score 2 indicates that the infant appears to be doing well in that developmental domain.	
<b>RATING SCORE 1: SOMEWHAT EFFICIENT</b>	<b>A SCORE CLOSE TO THE EXPECTED TYPICAL OUTCOME</b>
A score of 1 indicates that an infant needs occupational therapy with further monitoring.	
<b>RATING SCORE 0: INEFFICIENT</b>	<b>A SCORE BELOW TO THE EXPECTED TYPICAL OUTCOME</b>
A score of 0 indicates that the infant needs to be referred for further investigation and examinations.	

**PREFERENTIAL WARM-UP GAME WITH RABBIT**

Preferential looking is based on the infant’s preference for colour, objects, contrast, contours, faces, direction and speed of the movement of targets and against a patterned/plain; a moveable/non-moveable background. To familiarise the infant with the targets and procedures to follow, play a hide and seek game for 2 min. Apply the base-line principles as set out in Table G.4.

Table G.3: Baseline principles

Position	Infants sits in a supportive sitting position on the PCG’s lap. The administrator should not look at the eyes/face of the PCG or communicate to the PCG during the measurement.
Equipment	Make sure the equipment is set at the position and angles. The examiner needs to be familiar with the procedures.
Quiet alert state	In preparation for administration the infant needs to be in a quiet alert state. During the quiet alert state, infants may focus on visual or auditory stimuli with a bright look and without thrusting movements.
Attention	The infant needs to be engaged before the measurement starts. See Table F.1 for examples.

**THE GAME**

Tap on the back of the stimulus card until the infant focuses and use:  
**VP: “Peter (name calling first), where is the rabbit?”**  
 As infant fixates on the board, a rabbit appears above and in the center of the board.  
 Wiggle the rabbit for 5 s and use:  
**VP: “Peter, (name calling first), Hallo, Hallo !**  
 Take the rabbit away and repeat the procedure for the left and right side as seen in Figure G.1

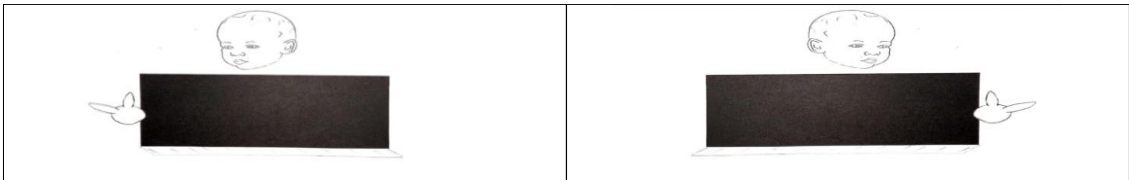


Figure G.1: Warm-up preferential looking game with a toy rabbit.

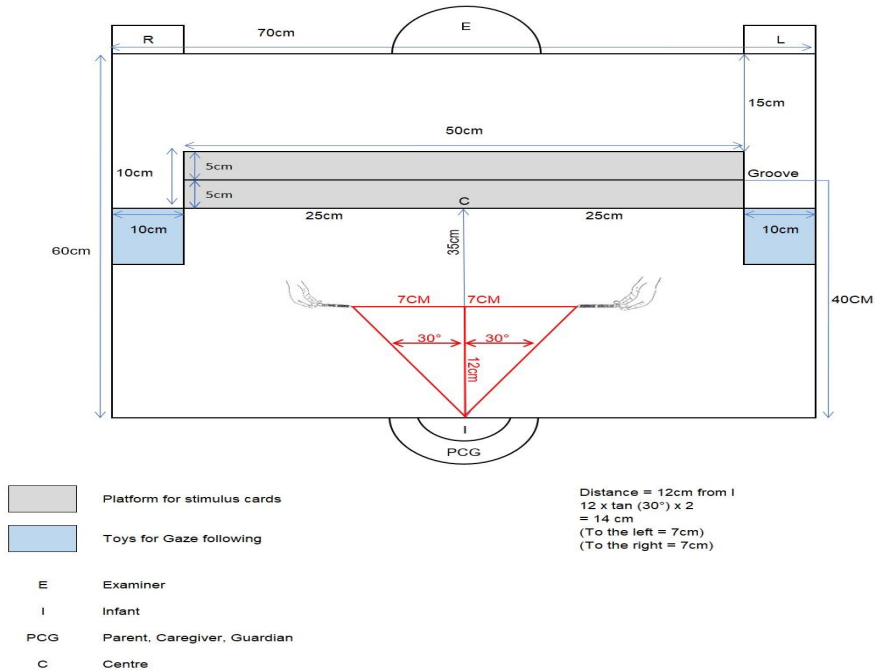
**BREAKTIME**

Apply breaktimes as stipulated in the administration and scoring manual. Pacifiers can be given to the infant during breaktime. Inform and explain to the caregiver in advanced what are expected from them during these breaktimes. See Table F.2 for more details.

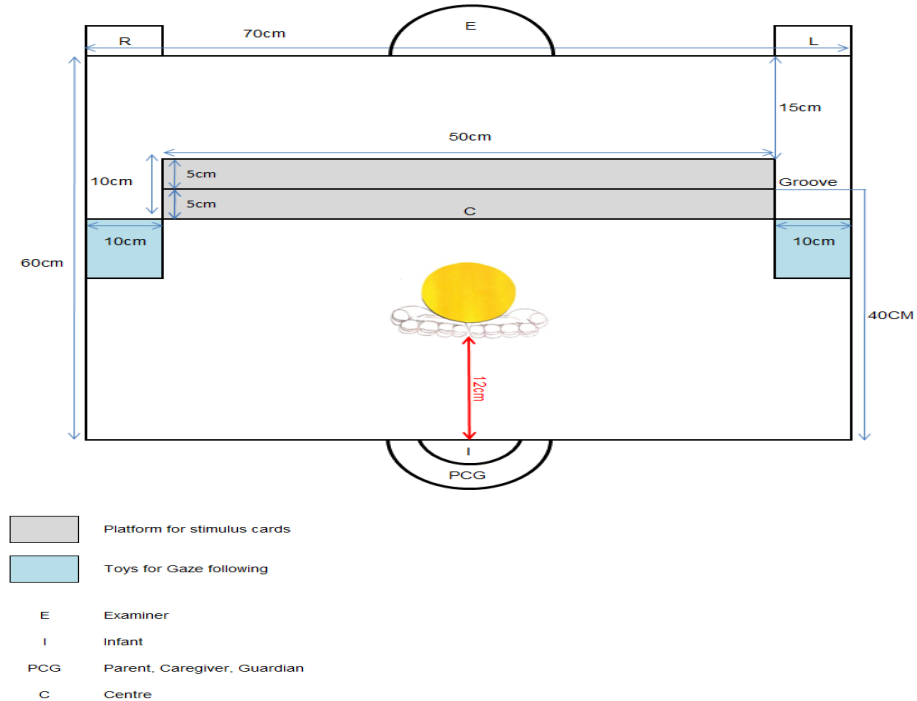
### A. FUNCTIONAL VISION FOR PARTICIPATION

<b>Item 1</b>	Look, reach, grasp, hold and release rattle with the right hand
<b>Item 2</b>	Look, reach, grasp, hold and release rattle with the left hand
<b>Item 3</b>	Looking, reaching, touching and holding a ball, with both hands to midline
<b>Item 4</b>	Adaptive reach with tactile input

**Figure G.2: Floor plan for item 1 and 2**




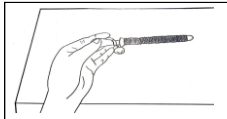

**Figure G.3: Floor plan for item 3**



Voluntary Eye Movement Measurement Tool  
(VEMMT)

**1. LOOK, REACH, GRASP, HOLD AND RELEASE RATTLE WITH THE INFANT'S RIGHT HAND**

Looking, reaching for, grasping, holding and releasing an object placed at 30° is registered as one-handed to the left and to the right

<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Rattle, 12 cm in length. <b>Distractor</b> Colourful pom-pom. <b>Positioning</b> The height of table needs to be at the centre of the infant's trunk to free arms.</p> 
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p>Hide the rattle under the table. Examiner holds it horizontally in her/his left hand. Keep the right hand under the table with a distractor.</p> <p style="text-align: center;"><b>Examiner is not allowed to look at the rattle, keep eye contact with the infant.</b></p> <p>Present the rattle horizontally from the infant's right midline and use non-verbal prompt. Use the marker on the mat for placement of the rattle and use verbal prompt. (The examiner's hand rest on table).</p> 
<p><b>PROMPT</b></p>	<p><b>Non-verbal Prompt</b> Wiggle the rattle to make a sound.</p> <p><b>Verbal prompt</b> " Peter, (voice calling first), look, you can take it"</p>
<p><b>REACH, GRASP, HOLD AND REALESE</b></p>	<p>Allow time for infant to play. Present a distractor with your right hand, to release attention from rattle, to remove rattle after 10 s.</p> 
<p><b>OUTCOME CRITERIA</b></p>	<p><b>Look</b> Head turn and eye movement directly and immediately to the toy on the right. <b>Reach</b> Initiates and reaches easily, smoothly, directed to the rattle with the right hand matches the orientation of rattle: palm facing down. <b>Grasp</b> Right hand is open on approach and grasps rattle with a palmar grasp. <b>Holds</b> Holds rattle and shows an attempt to play for 10 s. Shakes it, plays unilateral or with both hands. <b>Release</b> Transfers toy from one hand to another, taking to mouth to assist with transfer or drops it.</p>
<p><b>ATTEMPTS</b></p>	<p>If rattle drops in the 10 s period it can be presented again with the same procedures. Stopped after the second attempt. After 10 s present the visual distractor to remove the rattle.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING</b>		
<b>LOOK: HEAD AND EYES TO THE TOY ON RIGHT SIDE</b>		
<b>SCORE</b>	<b>2</b>	<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>		Head turn and eye movement directly and immediately to the the toy on the right.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Need multiple prompts by shaking the rattle before infant engages with the toy.
<b>INEFFICIENT</b>	<b>0</b>	No attempt to turn head and eyes to the toy rattle.

<b>SCORING</b>		
<b>REACH: RIGHT HAND REACH FOR RATTLE</b>		
<b>SCORE</b>	<b>2</b>	<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>		Initiates and reaches easily, smoothly, directed to the rattle, right hand matches the orientation of rattle; palm facing down.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Reaches for the rattle after more than two prompts. Delay in response with poor accuracy.
<b>INEFFICIENT</b>	<b>0</b>	Does not reach for the rattle, although arms may activate.

<b>SCORING</b>		
<b>GRASP: RIGHT HAND GRASP FOR RATTLE</b>		
<b>SCORE</b>	<b>2</b>	<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>		Hands on approach open. Uses a palmar grasp with ease
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Thumb is inactive, and fingers move as a unit in a grasp attempt. Hand not shaped for a palmar grasp.
<b>INEFFICIENT</b>	<b>0</b>	Partially opens hands in grasp attempt. Does not grasp.


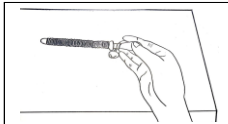

<b>SCORING</b>		
<b>HOLDING: RIGHT HAND RATTLE HOLD</b>		
<b>SCORE</b>	<b>2</b>	<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>		Holds toy rattle for 10 s in hand with hand unsupported (in space).
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Shows minimal interest and maintains contact less than 10 s.
<b>INEFFICIENT</b>	<b>0</b>	Does not retain the rattle.

<b>SCORING</b>		
<b>RELEASE: ACTIVELY RELEASE RATTLE WITH RIGHT HAND</b>		
<b>SCORE</b>	<b>2</b>	<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>		Transfers rattle from one hand to the other with ease. Actively release rattle on table or on floor.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Shows an attempt to open hand but was not successful.
<b>INEFFICIENT</b>	<b>0</b>	Release: Is unaware of release

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**2. LOOK, REACH, GRASP, HOLD AND RELEASE RATTLE WITH THE LEFT HAND**

Looking, reaching for, grasping, holding and releasing an object placed at 30° is registered as one-handed to the left and to the right.

<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Rattle, 12 cm in length size. <b>Distractor</b> Colourful pom-pom. <b>Positioning</b> The height of table needs to be at the centre of the infant's trunk to free arms.</p> 
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p>Hide the rattle under the table. Examiner holds it horizontally in her/his right hand. Keep the left hand under the table with a distractor.</p> <p style="text-align: center;"><b>Examiner is not allowed to look at the rattle, keep eye contact with the infants.</b></p> <p>Present the rattle horizontally, from the infant's left midline and use non-verbal prompt. Use the marker on the mat for placement of the rattle and use verbal prompt. (The examiner's hand rest on table).</p> 
<p><b>PROMPT</b></p>	<p><b>Non-verbal Prompt</b> Wiggle the rattle to make a sound.</p> <p><b>Verbal</b> " Peter, (voice calling first), look, you can take it"</p>
<p><b>REACH, GRASP, HOLD AND REALESE</b></p>	<p>Allow time for infant to play. Present a distractor with your left hand, to release attention from rattle, to remove rattle after 10 s.</p> 
<p><b>OUTCOME CRITERIA</b></p>	<p><b>Look</b> Head turn and eye movement directly and immediately to the toy on the left side. <b>Reach</b> Initiates and reaches easily, smoothly, directed to the rattle with the left hand matches the orientation of rattle: palm facing down. <b>Grasp</b> Left hand is open on approach and grasps rattle with a palmar grasp. <b>Holds</b> Holds rattle and shows an attempt to play for 10 s. Shakes it, plays with both hands. <b>Release</b> Transfers toy from one hand to another, taking to mouth to assist with transfer or drop it.</p>
<p><b>ATTEMPTS</b></p>	<p>If rattle drops in the 10 s period it can be presented again with the same procedures. Stopped after the second attempt. After 10 s present the visual distractor to remove the rattle.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING</b>		
<b>LOOK: HEAD AND EYES TO THE TOY ON LEFT SIDE</b>		
<b>SCORE</b>	<b>2</b>	<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Head turn and eye movement directly and immediately to the the toy on the left side.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Need multiple prompts by shaking the rattle before infant engages with the rattle.
<b>INEFFICIENT</b>	<b>0</b>	No attempt to turn head and eyes to the rattle.

<b>SCORING</b>		
<b>REACH: LEFT HAND REACH FOR RATTLE</b>		
<b>SCORE</b>	<b>2</b>	<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Initiates and reaches easily, smoothly, directed to the rattle; left hand matches the orientation of rattle; palm facing down.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Reaches for the rattle after more than two prompts. Delay in response with poor accuracy.
<b>INEFFICIENT</b>	<b>0</b>	Does not reach for the rattle, although arms may activate.

<b>SCORING</b>		
<b>GRASP: LEFT HAND GRASP FOR RATTLE</b>		
<b>SCORE</b>	<b>2</b>	<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Hands on approach open. Uses a palmar grasp with ease.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Thumb is inactive, and fingers move as a unit in a grasp attempt. Hand not shaped for a palmar grasp.
<b>INEFFICIENT</b>	<b>0</b>	Partially opens hands in grasp attempt. Does not grasp.




<b>SCORING</b>		
<b>HOLDING: LEFT HAND RATTLE HOLD</b>		
<b>SCORE</b>	<b>2</b>	<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Holds the toy rattle for 10 s in hand with hand unsupported (in space).
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Shows minimal interest and maintains contact less than 10 s.
<b>INEFFICIENT</b>	<b>0</b>	Does not retain the rattle.

<b>SCORING</b>		
<b>RELEASE: ACTIVELY RELEASE RATTLE WITH LEFT HAND</b>		
<b>SCORE</b>	<b>2</b>	<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Transfers rattle from one hand to the other with ease. Actively release rattle on table on floor.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Shows an attempt to open hand but was not successful.
<b>INEFFICIENT</b>	<b>0</b>	Release: Is unaware of release.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**3. LOOKING, REACHING, TOUCHING AND HOLDING A BALL, WITH BOTH HANDS TO MIDLINE**

A two-handed reach is defined as both hands approaching the object simultaneously, to actively hold the presented ball.

<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Yellow plastic smooth ball, 13 cm in diameter. <b>Distractor</b> Colourful pom-pom. <b>Positioning</b> The height of table needs to be at the centre of the infant's trunk to free arms.</p> 
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p>Hide the ball under the table. The examiner does not look at the ball, she/he keeps eye contact with the infant. Present the ball in front and in the middle with both hands at the 12 cm marker and use non-verbal prompt. Stop wiggling the ball and use verbal prompt.</p> 
<p><b>PROMPT</b></p>	<p><b>Non-verbal</b> Wiggle the ball. <b>Verbal</b> " Peter (voice calling first), look, it is a ball, take it".</p>
<p><b>REACH, GRASP, HOLD AND REALESE</b></p>	<p>Allow time for infant to play. Present a distractor to release attention from ball, to remove the ball after 10 s.</p>
<p><b>OUTCOME CRITERIA</b></p>	<p><b>Look</b> Head and eyes movement directly and immediately to the ball. <b>Reach</b> Initiates and reaches easily, smoothly, directed to the ball with both hands simultaneously. <b>Grasp/Touching</b> Grasp ball with open fingers. <b>Holds</b> Holds ball and shows an attempt to play for 10 s. <b>Release</b> Drops ball with open hands.</p>
<p><b>ATTEMPTS</b></p>	<p>If ball drops in the 10 s period it can be presented again with the same procedures. Stopped after the second attempt. After 10 s present the visual distractor to remove the ball. Score the best performance.</p> <p style="text-align: center;"><b>Distract with colourful pom-pom.</b></p> 
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING</b> <b>LOOK: HEAD AND EYES TO THE BALL</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Head turn and eye movement directly and immediately to the the ball.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Need multiple prompts by shaking the hand before infants engages with the ball.
<b>INEFFICIENT</b>	<b>0</b>	No attempt to turn head and eyes to the toy ball.

<b>SCORING</b> <b>REACHING: REACHING FOR BALL WITH BOTH HANDS</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Reaches forward with both hands simultaneously for the ball.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Reaches forward with a difference on one side. Difference in equilateral range.
<b>INEFFICIENT</b>	<b>0</b>	Difficulty reaching, limited range.Does not try to reach.

<b>SCORING</b> <b>GRASP: TOUCHING WITH BOTH HANDS</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Hands on approach open.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Thumb is inactive, and fingers move as a unit in a grasp attempt. Hand not shaped to grasp ball.
<b>INEFFICIENT</b>	<b>0</b>	Partially opens hands in grasp attempt. Does not grasp.




<b>SCORING</b> <b>HOLDING: BALL WITH BOTH HANDS</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Holds ball for 10 s with hands unsupported (in space).
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Shows minimal interest and maintains contact less than 10 s.
<b>INEFFICIENT</b>	<b>0</b>	Does not retain the ball.

<b>SCORING</b> <b>RELEASE: ACTIVELY RELEASE BALL</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Actively release ball.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Shows an attempt to open hand but was not successful.
<b>INEFFICIENT</b>	<b>0</b>	Release: Is unaware of release

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**4. ADAPTIVE REACH WITH TACTILE INPUT**

Adaptive motor skills response is the ability to plan and act on an object with a tactile input in an organised way.

<b>EQUIPMENT</b>	<p><b>Toy</b> Sticky piece of 6.5 cm tape with a red dot of 1.5 cm. <b>Distractor</b> Colourful pom-pom with sound toy for distraction. <b>Positioning</b></p> 
<b>PROCEDURE</b>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p>Ask the PCG to gently hold the infant's arms in front. Raise your eyebrow with a smile and show the tape. Put the tape on your hand, cover it with your hand and play peek-a-boo with the tape. Place the strip of tape, with the red dot in the middle of the tape, on the back of the infant's left or right hand, leaving the ends free and use verbal prompt.</p> <p style="text-align: center;">Wait for 30 s.</p> 
<b>PROMPT</b>	<p><b>Verbal prompt</b> " Peter, (voice calling first), look what I put on your hand, go get it".</p>
<b>OUTCOME CRITERIA</b>	<p>Infant turns head and eyes to tape on his/her hand. Infant tolerates tape on hand. Bring hands to midline, reach is directed to the tape, touches, grasps and removes tape from other hand, through successive attempts. Infant keeps state of alertness without getting upset or fuzzy.</p>
<b>ATTEMPTS</b>	<p>If no attempts encourage by wiggle the ends. Tap softly on the red dot.</p>
<b>REMOVAL OF TAPE</b>	<p>To remove the tape, present a distractor, a colourful pom-pom, to the infant.</p>  <p>Remove the tape softly after 30 s if the infant cannot do so. If removed by infant, ask for it and say, "I take it". Remove it from the infant before the infant has an attempt to put into the mouth.</p>
<b>BREAK</b>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

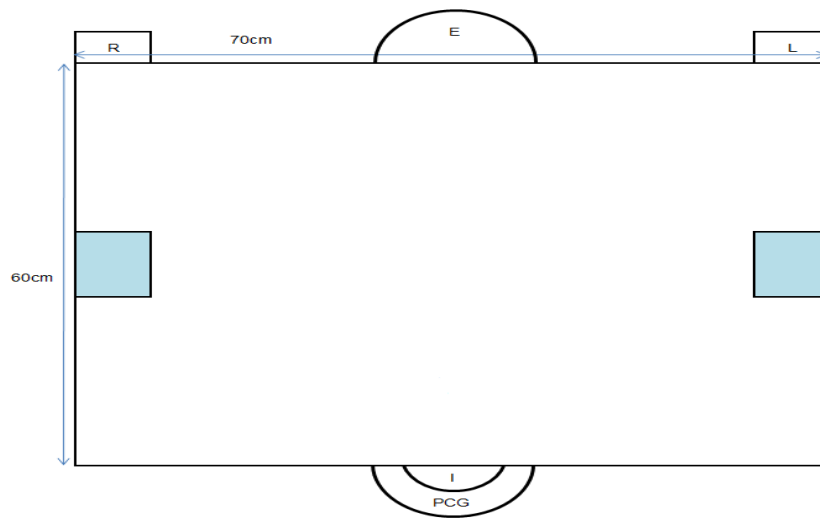
Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING</b>		
<b>ADAPTIVE REACH WITH TACTILE INPUT</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	<p>Infant turns head and eyes to tape on his/her hand. Infant tolerates tape on hand.</p> <p>Bring hands to midline, reach is directed to the tape, touches, grasps and removes tape from other hand through successive attempts. Infant keeps state of alertness without getting upset or fuzzy.</p>
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	<p>Hands to midline, touches the tape but unsuccessful in removing it. Needs prompts for duration of 30 s.</p>
<b>INEFFICIENT</b>	<b>0</b>	<p>Retract the arm and does not bring hands to midline to remove the tape. Infant shows discomfort, turn to the mother, shows flailing, disorganized movements and is in distress.</p>

## B. SOCIAL INTERACTIONS

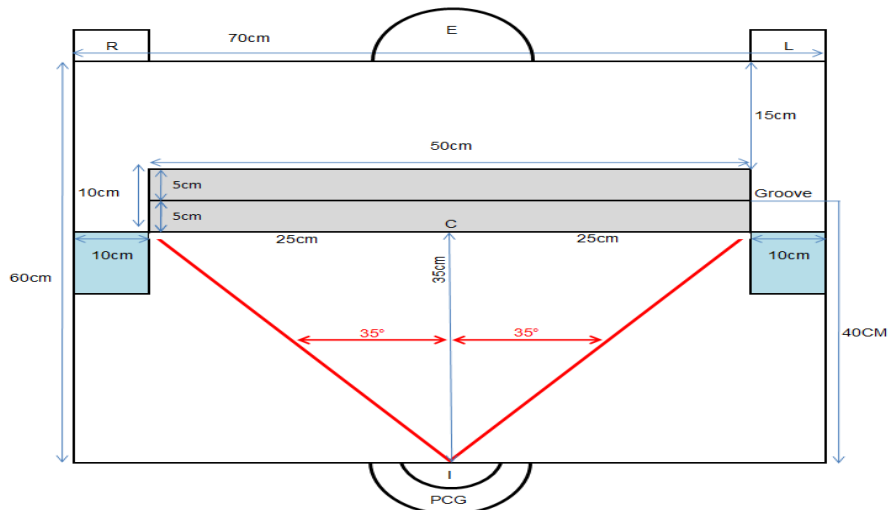
Item 5	Peek- a- Boo
Item 6	Gaze Following



**Figure G.4: Floor plan for item 5**



E Examiner  
 I Infant  
 PCG Parent, Caregiver, Guardian

**Figure G.5: Floor plan for item 6**



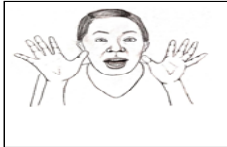


 Platform for stimulus cards  
 Toys for Gaze following

Distance = 35cm  
 PVF = 35°  
 From C to L = 25cm  
 From C to R = 25cm  
 $2 \times (35 \times \tan(35))$   
 = 50cm

E Examiner  
 I Infant  
 PCG Parent, Caregiver, Guardian  
 C Centre

Voluntary Eye Movement Measurement Tool  
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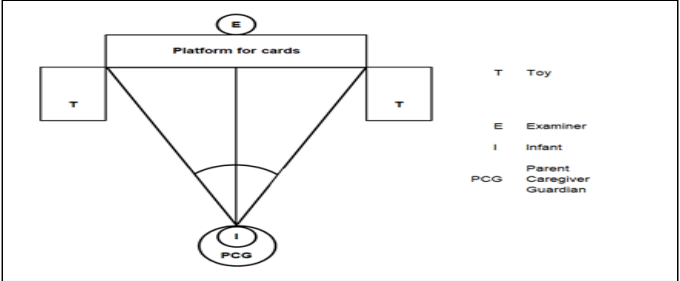


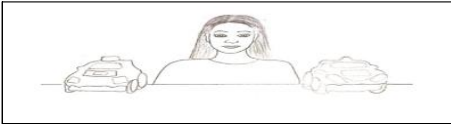
<b>5. PEEK-A-BOO</b>	
Social brain activation is by reading social interaction cues during direct gaze (holding) and shifts (gaze shifting).	
<b>EQUIPMENT</b>	<p><b>Toy</b> Play Peek-a-Boo- Game.</p> <p><b>Positioning</b></p>  <p>Infant on mother's lap in supportive sitting position at a desk. Examiner sits opposite infant at table, hide your hands under the table. Examiner's distance is 60 cm from infant.</p>
<b>PROCEDURE</b>	<p style="text-align: center;"><b>Apply the baseline principles.</b></p> <p>Put your hands in front of your face and say: "I am not here" for 2 s.</p>  <p>Expose your face, hands next to your face: - fingers expanded - with a direct gaze - eyebrow lift</p> <p>Use verbal prompt: "Baa-Baa". Keep smiling for 5 s.</p>  <p>Hide your face again. Repeat once more (Two play session of the game Peek-A-Boo.)</p>
<b>OUTCOME CRITERIA</b>	<p>Direct eye contact with the examiner. Social responses like body movements and smile.</p>
<b>ATTEMPTS</b>	<p>Complete the play sessions. Stop if infant is in distress after first play.</p>
<b>BREAK</b>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

Voluntary Eye Movement Measurement Tool  
(VEMMT)



<b>SCORING</b>		
<b>SOCIAL INTERACTION: PEEK-A-BOO PLAY</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Direct eye contact during the two play sessions.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Momentarily direct gaze.
<b>INEFFICIENT</b>	<b>0</b>	No engagement, avert gaze.

**6. GAZE FOLLOWING**

Gaze following is the ability to look where somebody else is looking and is a fundamental element of face-to-face interaction, a precursor to language development and part of inter-relationships between perceptual-cognitive and social development.

<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Two bright play cars. The dimensions are 12 cm in height, 14 cm in length and 10 cm in width.</p> <p><b>Positioning</b> Examiner sits opposite the infant. Infants sits at table with arms free.</p>  <p><b>Placement of the toys</b> Examiner places the toys at the corners in front of the platform, as indicated on the mat.</p> 
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES.</b></p> <p style="text-align: center;"><b>TO THE INFANT'S LEFT / EXAMINER'S RIGHT</b></p> <p>Place the toys on the markers and the examiner removes his/her hands from table.</p> <p>A. Examiner lowers her head and gaze down for 2 s.</p>  <p>B. Keep gaze lowered but slightly lift the head and make rapid horizontal head shakes for 2 s (social and non-ostensive prompt).</p>  <p>C. Examiner has direct gaze with the infant, raises eyebrow and smiles for 2 s (social and ostensive prompt).</p> 

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	<p>D. Examiner turns her/his head and eyes to <b>her/his right</b>. Keep gaze at toy and say: "Wow, look, hallo" for 5 s.</p>  <p>E. Moves head and eyes back to the infant to reconnect and interact by smiling and talking until infant makes eye contact and is in a regulatory state.</p> <p><b>REPEAT TO THE INFANT'S RIGHT / EXAMINER'S LEFT</b> Repeat A, B, C steps from above.</p> <p>Step D: Examiner turns her/his head and eyes to <b>her/his left</b>. Keep gaze at toy and say: "Wow, look, hallo " for 5 s.</p>  <p>Step E: Moves head and eyes back to the infant to reconnect and interacts by smiling and talking until infant makes eye contact and is in a regulatory state.</p>
<b>OUTCOME CRITERIA</b>	Infant shows an interest in all the above steps and successfully follows the examiner's gaze to both sides.
<b>ATTEMPTS</b>	Only one attempt to each side
<b>BREAK</b>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

Voluntary Eye Movement Measurement Tool  
(VEMMT)

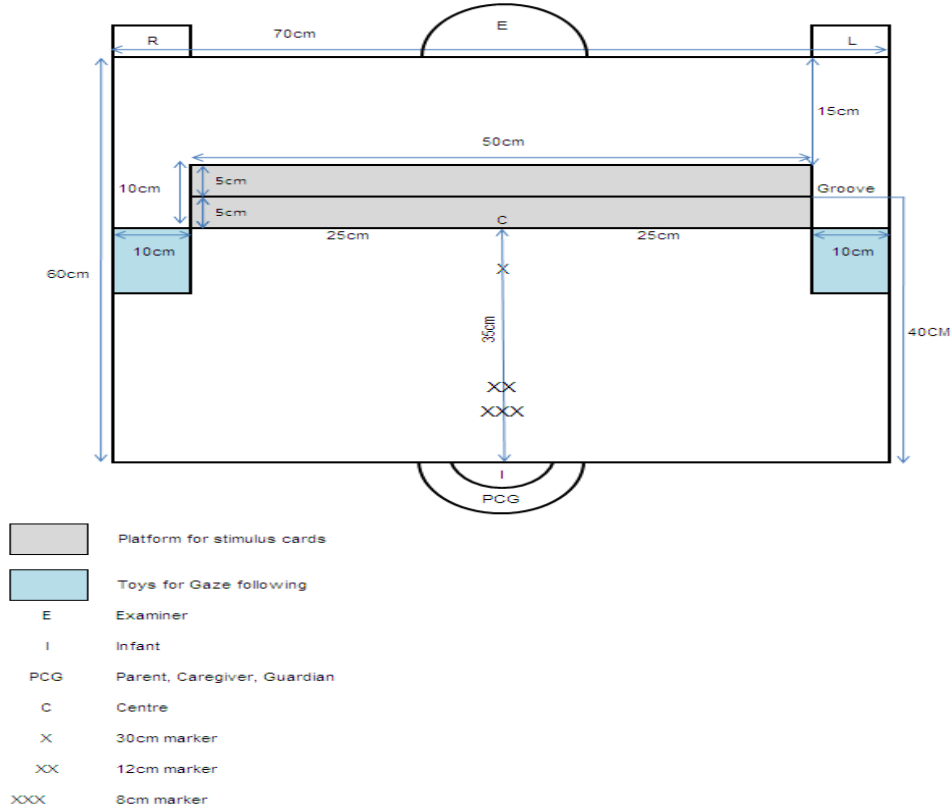
<b>SCORING</b>		
<b>GAZE FOLLOWING TO THE EXAMINER'S RIGHT</b>		
<b>SCORE</b>	<b>2</b>	<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Shows social interaction by eye contact and follows the gaze of the examiner successfully.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Slow in response to follow and shows no interest in toy with limited attention.
<b>INEFFICIENT</b>	<b>0</b>	No attempt to follow the gaze of the examiner and did not participate. Not successful with the first and only attempt.

<b>SCORING</b>		
<b>GAZE FOLLOWING TO THE EXAMINER'S LEFT</b>		
<b>SCORE</b>	<b>2</b>	<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Shows social interaction by eye contact and follows the gaze of the examiner successfully.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Slow in response to follow and shows no interest in toy with limited attention.
<b>INEFFICIENT</b>	<b>0</b>	No attempt to follow the gaze of the examiner and did not participate. Not successful with the first and only attempt.

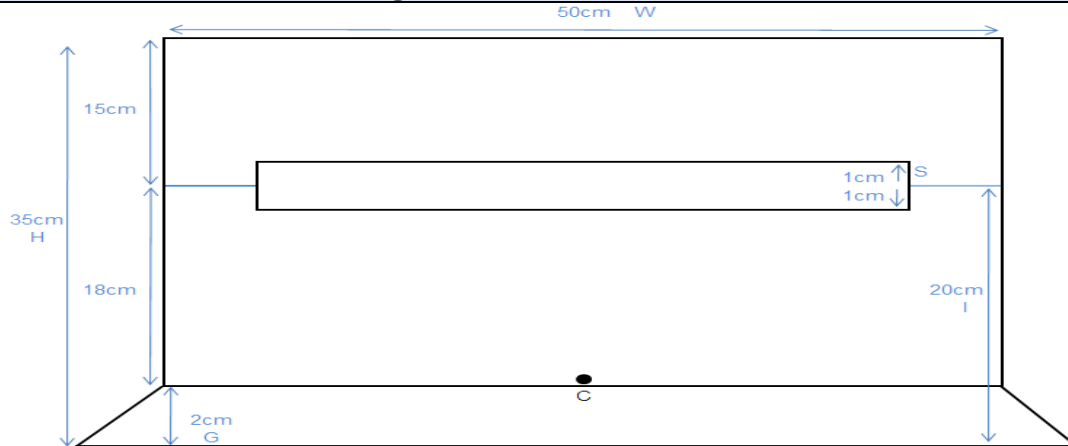
C. GAZE HOLDING

<b>Item 7</b>	Muscle balance in different directions
<b>Item 8</b>	Direct penlight reflection
<b>Item 9</b>	Ocular alignment cover/uncover
<b>Item 10</b>	Convergence

**Figure G.6: Floor plan for items 7, 8, and 10**



**Figure G.7: Platform for item 7**



- Centre
- H Height = 35cm
- W Width = 50cm
- G 2cm in groove
- S Size of opening of slit 2cm
- I The middle of the slit is the same as the level of the infants eye - 20cm

Figure G.8: Stimulus card for item 7

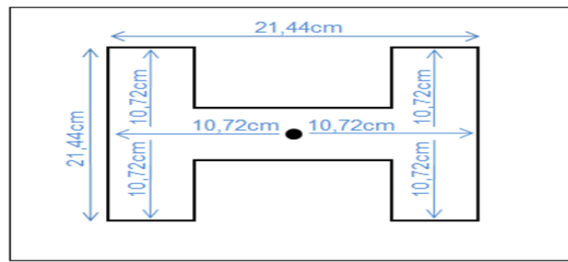


Figure G.9: Stimulus card for item 10

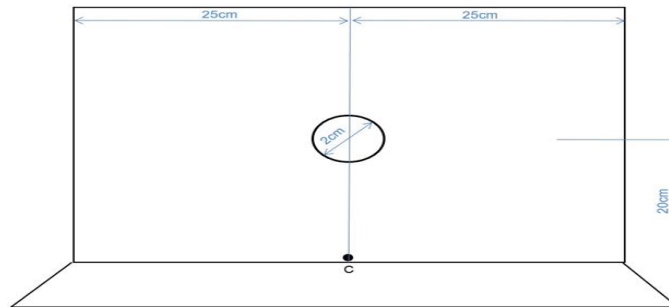
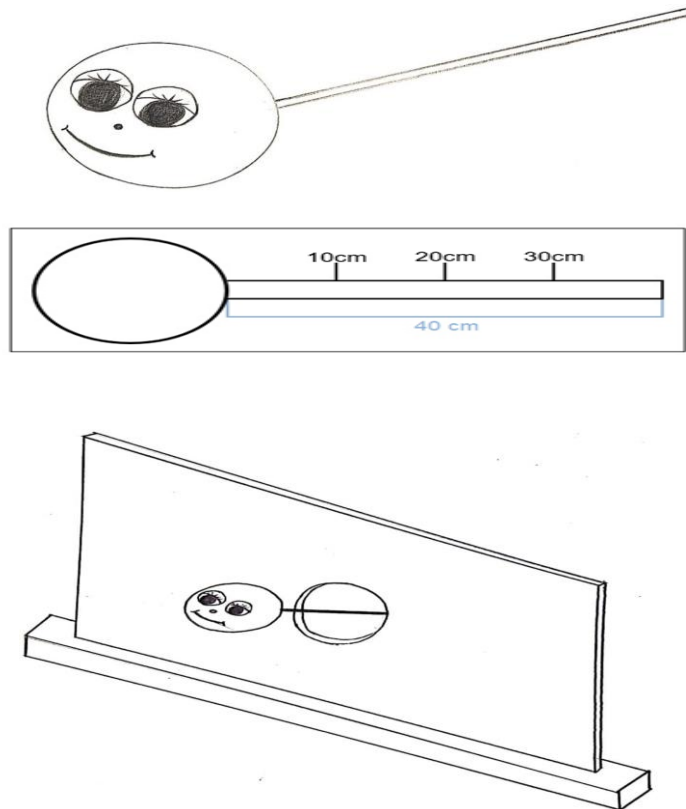


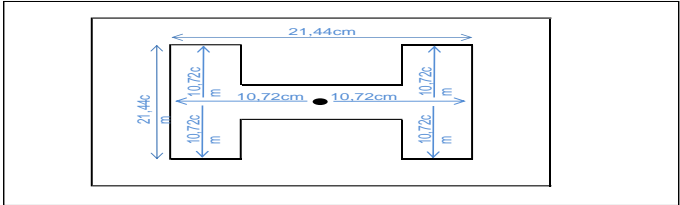
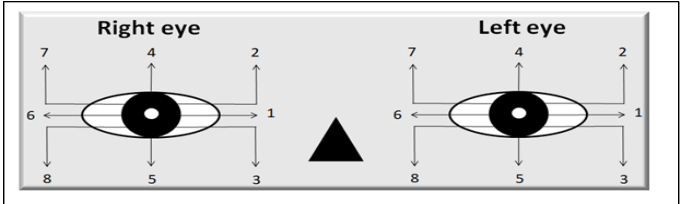
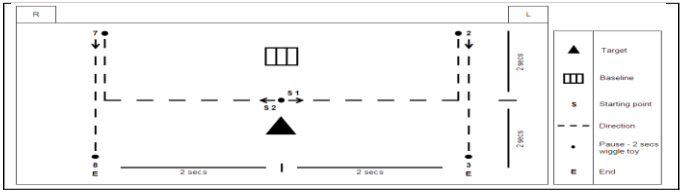
Figure G.10: Convergence stick and platform for item 10



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(VEMMT)

**7. MUSCLE BALANCE IN DIFFERENT DIRECTIONS**

Alignment acts as a platform for binocular sensory development. Binocular alignment is when the image of the object of regard falls simultaneously on the fovea of each eye, and the vertical retinal meridians are both upright due to coordinated extra-ocular muscles.

<p><b>EQUIPMENT</b></p>	<p><b>Toys</b> Picture fixation stick faces.</p> <p><b>Positioning of platform and stimulus card</b> Use the H stimulus card mounted on platform.</p>  <p><b>Placement of target</b> Place the face toy fixation target in the centre of frame. The nine positions of gaze need to be observed and recorded as per illustration below. Start with target in primary gaze i.e., straight ahead and then proceed as indicated below.</p>  <p><b>Direction 1,6,4, and 5 will be observed and scored during item 11 and 12.</b></p>
<p><b>PROCEDURE</b></p>	<p><b>APPLY THE BASELINE PRINCIPLES</b> <b>Directional/ Movement (Illustration at the back of stimulus card)</b></p>  <p>Place the fixation face in the center, use verbal prompt.</p> <p>At S1 (centre point) wiggle the face for 2 s, then keep the face still for 2 s. Again, wiggle face for 2 s and follow the direction of S1. Move to point 2 without stops and follow the speed indicators. At point 2, the pause dot, stop, wiggle the face for 2 s, then keep the face still for 2 s. Again, wiggle the toy for 2 s before moving the target to the bottom end, point 3. At the pause dot, stop, wiggle the face for 2 s, then keep the face still for 2 s. Use end prompt.</p> <p><b>Replace the new target for S2</b> and repeat the same procedures to reach point 7 and 8 by following S2.</p>
<p><b>PROMPT</b></p>	<p>Starting prompt: "Peter, (voice calling first) look, it is a baby. The baby walks away". End Prompt: "Peter, bye-bye".</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>Complete smoothly without being distracted and without head movement. Can maintain the eye position at the end ranges.</p>
<p><b>ATTEMPTS BREAK</b></p>	<p>Only one attempt for each direction.</p> <p><b>"BREAKTIME"</b> Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>


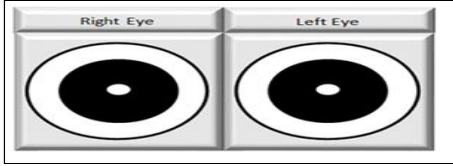
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<b>SCORING</b> <b>MUSCLE BALANCE IN DIFFERENT DIRECTIONS</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b> <b>SCORING FOR 1, 2, 3, 4, 5, 6, 7, 8 AND 9 (CENTRAL)</b>
<b>EFFICIENTLY</b>	<b>2</b>	Moves both eyes smoothly without head movement. Maintains the eye alignment during movement and at ALL nine end ranges for 2 s.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Slight movement of head and or jerky following movement. Needs to wiggle the toy more than once at the starting and ending point to capture the infant's attention at end position but can move eyes without deviation. Eyes tends to jump back to the middle cannot maintain the eye position at end ranges.
<b>INEFFICIENT</b>	<b>0</b>	Large movement of head. One eye or both eyes were consistently misaligned. Not successful with the first and only attempt.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**8. OCULAR ALIGNMENT/CORNEAL/DIRECT PENLIGHT REFLECTION MEASUREMENT.**

Alignment acts as a platform for binocular sensory development. Binocular alignment is when the image of the object of regard falls simultaneously on the fovea of each eye, and the vertical retinal meridians are both upright.

<p><b>EQUIPMENT</b></p>	<p><b>Toy Target</b> Penlight. <b>Positioning</b> Infants sits supported on the PCG's lap. Keep the penlight at a distance of 30 cm from infant's face, the XX marker on the mat.</p>
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p>Play opposite the nose bridge of infant in the center by wiggling the light and use verbal prompt. Wiggle the light softly and when the infant fixates, stop and shine the penlight in the middle of nose bridge of infant for 2 s.</p> <div style="text-align: center;">  </div>
<p><b>PROMPT</b></p>	<p><b>Verbal Prompt</b> "Peter (voice calling first) look at the light".</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>The light should be in the center in both eyes.</p> <div style="text-align: center;">  </div>
<p><b>ATTEMPTS</b></p>	<p>If examiner observes the reflection in both eyes the measurement is stopped. If not or unsure of the outcome, repeat the procedures once more.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING</b> <b>DIRECT PENLIGHT REFLECTION MEASUREMENT</b> <b>DIRECT OBSERVATION WITH IMMEDIATE SCORING</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Keep head in midline and reflection is in the center in both pupils for the 2 s.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Keep head in midline. Can keep the eyes aligned momentarily, then lose fixation.
<b>INEFFICIENT</b>	<b>0</b>	Head tilt. Reflection not in the center in right and/or left eye.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**9. OCULAR ALIGNMENT COVER/UNCOVER MEASUREMENT**

Alignment acts as a platform for binocular sensory development. Binocular alignment is when the image of the object of regard falls simultaneously on the fovea of each eye, and the vertical retinal meridians are both upright.

<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Penlight <b>Positioning</b> Infant sits supported on the PCG's lap. Keep the penlight at a distance of 30 cm from infant's face, the XX marker on the mat.</p>
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p><b>1. Infant's right eye</b> Play opposite the nose bridge of infant in the center by wiggling the light and use verbal prompt. Wiggle the light softly and when the infant fixates, stop and shine the light for 2 s in the middle of nose bridge of infant.</p> <p><b>Right eye cover/uncover</b> After 2 s the examiner covers with her/his left hand the <b>right eye of infant for 2 s</b> (from above and hand fingers pointing down).</p> <div> </div> <p><b>Uncover the right eye</b> and observe the <b>right eye</b>. Both eyes should be looking at the target when uncover without movement.</p> <div> </div> <p><b>2. Infant's left eye</b> Play opposite the nose bridge of infant in the center by wiggling the light and use verbal prompt. Wiggle the light softly and when the infant fixates, stop and shine the penlight for 2 s in the middle of nose bridge of infant.</p> <p><b>Left eye cover/uncover</b> After 2 s the examiner covers with her/his <b>right hand</b> the <b>left eye of infant for 2 s</b> (from above and hand fingers pointing down).</p> <div> </div> <p><b>Uncover the left eye</b> and observe the <b>left eye</b>. Both eyes should be looking at the target when uncover without movement.</p> <div> </div>
<p><b>PROMPT</b></p>	<p><b>Verbal Prompt</b> "Peter (voice calling first) look it is a light".</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>No movement of LEFT OR RIGHT EYE when uncover. The infant can keep fixation on the light. Binocular viewing is present during the uncover measurement.</p> <div> </div>

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<b>ATTEMPTS</b>	One attempt for each eye
<b>BREAK</b>	<b>“BREAKTIME”</b> Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.




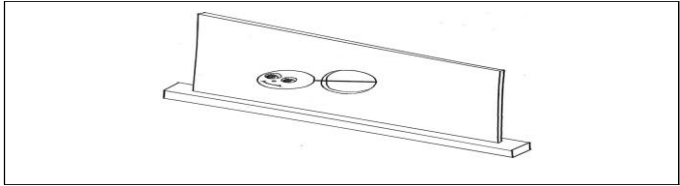
Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING</b> <b>COVER AND UNCOVER, DIRECT PENLIGHT REFLECTION</b> <b>DIRECT OBSERVATION WITH IMMEDIATE SCORING</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Keep head in midline. Binocular viewing is present during the uncover measurement.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Just momentarily then lose fixation.
<b>INEFFICIENT</b>	<b>0</b>	Head tilt with large deviation of right or left eye.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**10. CONVERGENCE**

Convergence is the process of using extra ocular muscles to direct the visual axis of the two eyes to a near point, a simultaneous process turning of the eyes inward.

<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Puppet face on a stick. The length of the stick is 40 cm. The face is a styro ball, 6 cm in diameter.</p>  <p><b>Positioning</b> Infants sits on the PCG's lap with support. Use the convergence stimulus card mounted on the base.</p> <p><b>Placement of target</b> Place the face-toy-stick in the center. Start with target in primary central gaze straight ahead.</p>
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p><b>Directional/movement</b></p>  <p>Place the toy in the center and use starting verbal prompt. Wiggle toy for 2 s, then keep the toy still for 2 s. Again, wiggle the toy for 2 s and follow the markers on the stick. Move the target at a speed of 1 cm for every 10 cm. Takes 3 s to reach the end. At the 12 cm marker on mat stop and keep toy still for 2 s. Use end prompt.</p>  
<p><b>PROMPT</b></p>	<p><b>Verbal Prompt</b> Starting Prompt: "Peter (voice calling first) look". End Prompt: "Peter, bye-bye".</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>Converge smoothly to the end without wiggling the toy during the movement.</p>
<p><b>ATTEMPTS</b></p>	<p>One attempt. If infant loses interest during the movement, the examiner may wiggle the toy once or twice for completion of distance to assist with attention holding with fixation.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

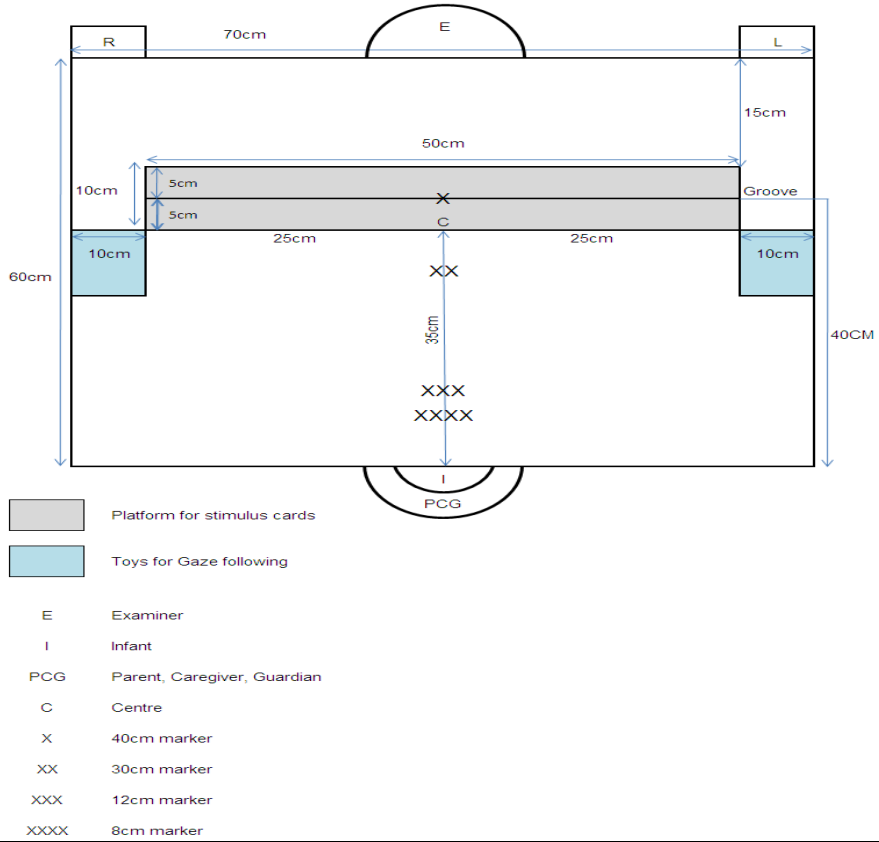
Voluntary Eye Movement Measurement Tool  
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<b>SCORING CONVERGENCE</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Converge smoothly to the end (12 cm) without wiggling the toy.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Infant's stop fixating at the toy before the end (12 cm). Need to wiggle the toy once or twice for completion of distance to assist with attention holding with fixation.
<b>INEFFICIENT</b>	<b>0</b>	Need to wiggle toy more than twice. Cannot maintain fixation for convergence between 40-12 cm. Not successful with the first and only attempt.

D. GAZE SHIFT, SMOOTH PURSUIT EYE MOVEMENTS (SPEM)

<b>Item 11</b>	Horizontal SPEM
<b>Item 12</b>	Vertical SPEM
<b>Item 13</b>	Circular clockwise SPEM
<b>Item 14</b>	Circular anti-clockwise SPEM

**Figure G.11: Floor plan for items 11, 12, 13, and 14.**



**Figure G.12: Platform for stimulus cards 11, 12, 13 and 14.**

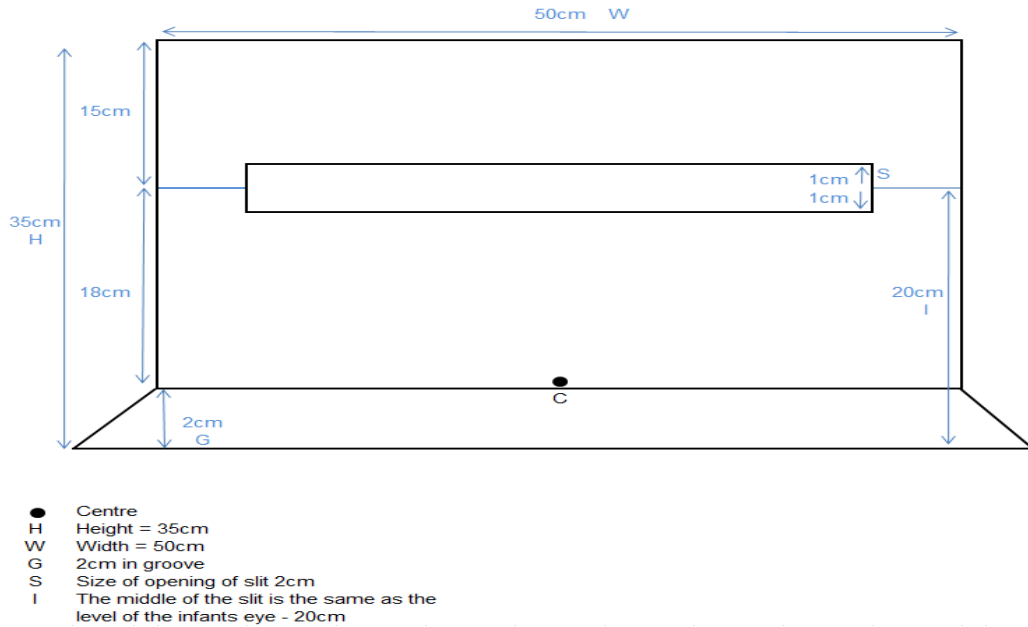
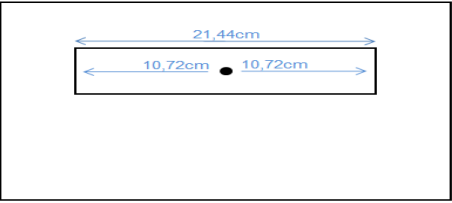
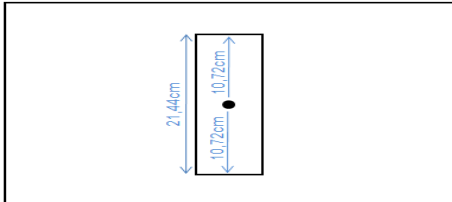
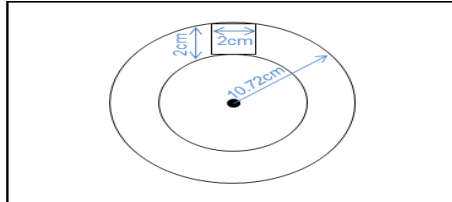
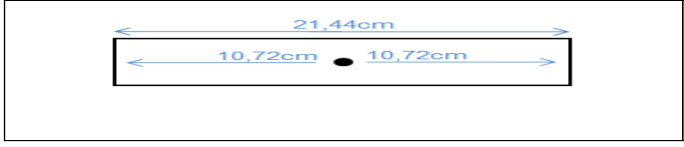
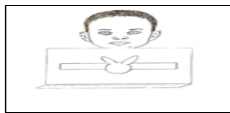
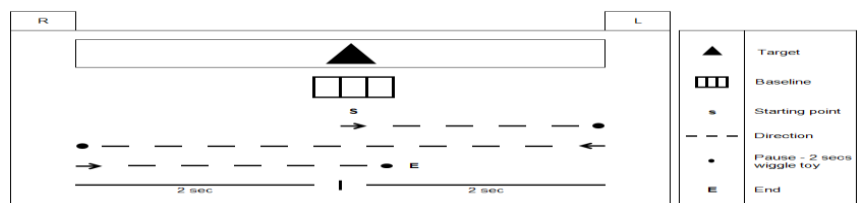


Figure G.13: Stimulus cards for items 11, 12, 13, and 14

Horizontal	 <p>A diagram of a horizontal stimulus card. It consists of a large outer rectangle and a smaller inner rectangle centered within it. A black dot is located at the center of the inner rectangle. Dimension lines indicate the following measurements: the width of the outer rectangle is 21.44cm, the width of the inner rectangle is 10.72cm, and the distance from the center dot to the left and right edges of the inner rectangle is 10.72cm.</p>
Vertical	 <p>A diagram of a vertical stimulus card. It consists of a large outer rectangle and a smaller inner rectangle centered within it. A black dot is located at the center of the inner rectangle. Dimension lines indicate the following measurements: the height of the outer rectangle is 21.44cm, the height of the inner rectangle is 10.72cm, and the distance from the center dot to the top and bottom edges of the inner rectangle is 10.72cm.</p>
Circular SPEM clockwise and anti-clockwise	 <p>A diagram of a circular stimulus card. It features two concentric circles with a black dot at their common center. Dimension lines indicate the following measurements: the radius of the inner circle is 10.72cm, the radius of the outer circle is 12.72cm (10.72cm + 2cm), and the thickness of the ring between the two circles is 2cm.</p>

**11. SMOOTH PURSUIT EYE MOVEMENT (SPEM): HORIZONTAL SPEM**

Smooth pursuit eye movements refer to smooth tracking movements by the eyes alone allowing the eyes to maintain foveal alignment with a moving target that is voluntarily selected against a stationary background. The purpose of SPEM is to stabilize moving objects on the retina and thereby enable the perception of object details.

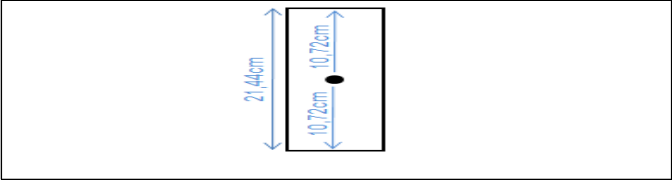

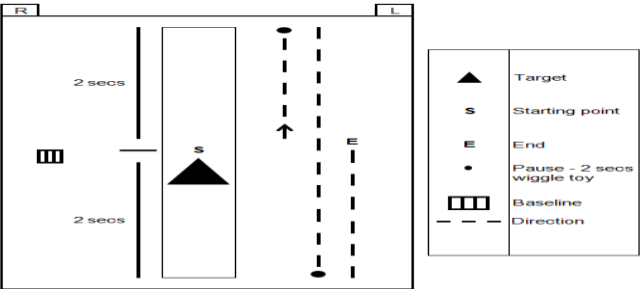
<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Animal toy for SPEM. Fixation face for eye alignment, item 7, nr 1 and 6. Horizontal SPEM stimulus card, mounted on base.</p>  <p><b>Positioning</b> Infant sits on the PCG's lap with support. Place the horizontal stimulus card on the platform. The procedures will be repeated twice. The first with an animal to administer SPEM. The second with the fixation face to administer the alignment of the eyes (Item 7, nrs 1 and 6). The same stimulus board for both items, but have different scoring criteria and target.</p>
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p>  <p><b>Directional/Movement</b> Place the toy at the S for start in the center of slit. Use starting verbal prompt. Wiggle toy for 2 s and move to the infant's left, (right side of E), by using the markers for the speed at the back of stimulus card. At the pause dot, stop, wiggle the toy for 2 s, then keep the toy still for 2 s. Again, wiggle the toy for 2 s before moving the toy to the infants right, (left side of E). At the pause dot, stop, wiggle the toy for 2 s, then keep the toy still for 2 s. Again, wiggle the toy for 2 s before moving the toy back to the center and use end prompt.</p> <p style="text-align: center;"><b>Scoring item 7 nr 1 and 6 Replace animal with fixation face</b></p> <p>Place the fixation face at the S for start in the center of slit. Use starting verbal prompt. Keep fixation face still for 2 s. Wiggle face for 2 s and move to the infant's left, (right side of E) by using the markers for the speed at the back of stimulus card. At the pause dot, stop, wiggle the face for 2 s, then keep the face still for 2 s. Again, wiggle the face for 2 s before moving the face to the infants right, (left side of E). At the pause dot, stop, wiggle the target for 2 s, then keep the target still for 2 s and use end prompt.</p> 
<p><b>PROMPT</b></p>	<p><b>Verbal Prompt</b> Starting Prompt: "Peter (voice calling first) look, it is a animal / baby". End Prompt: "Peter, bye-bye animal / baby".</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>Complete SPEM smoothly without being distracted and without head movement. Can maintain the eye position at the end ranges.</p>
<p><b>ATTEMPTS</b></p>	<p>One attempt.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

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SCORING HORIZONTAL SPEM		
<b>NOTE</b>		
<b>USE SPEM HORIZONTAL MEASUREMENT FOR SCORING 1 AND 6 OF MUSCLE BALANCE IN DIFFERENT DIRECTIONS (ITEM 7)</b>		
SCORE		CRITERIA FOR SCORING ITEMS
<b>EFFICIENTLY</b>	<b>2</b>	Completes smoothly without being distracted. Only eye movement. No head movement.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Completes with large movement of head. Intermittent distraction.
<b>INEFFICIENT</b>	<b>0</b>	Cannot complete the movement. No attempt to follow. Not successful with the first and only attempt.

**12. SMOOTH PURSUIT EYE MOVEMENT: VERTICAL (SPEM)**

Smooth pursuit eye movements refer to smooth tracking movements by the eyes alone allowing the eyes to maintain foveal alignment with a moving target that is voluntarily selected against a stationary background. The purpose of SPEM is to stabilize moving objects on the retina and thereby enable the perception of object details.

<p><b>EQUIPMENT</b></p>	<p><b>Target characteristic</b> Animal toy for SPEM. Fixation face for eye alignment, item 7, nr 4 and 5. Vertical SPEM stimulus card, mounted on base.</p>  <p><b>Positioning</b> Infant sits on the PCG's lap with support. Place the vertical stimulus card on the platform. The procedures will be repeated twice. The first with an animal to administer SPEM. The second with the fixation face to administer the alignment of the eyes (Item 7, direction 4 and 5). The same stimulus board but have different scoring criteria and target.</p>
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES.</b></p>  <p><b>Directional/Movement</b> Place the toy at the S for start in the in the center of slit. Use starting verbal prompt. Wiggle toy for 2 s and move <b>up</b> by using the markers for the speed at the back of stimulus card. At the pause dot, stop, wiggle the toy for 2 s, then keep the toy still for 2 s. Again, wiggle the toy for 2 s before moving the toy <b>down</b>. At the pause dot, stop, wiggle the toy for 2 s, then keep the toy still for 2 s. Again, wiggle the toy for 2 s before moving the toy to the center, stop and use end prompt.</p> <p style="text-align: center;"><b>Scoring Item 7 nr 4 and 5</b> <b>Replace animal with fixation face</b></p> <p>Place the fixation face at the S for start in the in the center of slit. Use starting verbal prompt. Wiggle face for 2 s and move <b>up</b> by using the markers for the speed at the back of stimulus card. At the pause dot, stop, wiggle the face for 2 s, then keep the face still for 2 s. Again, wiggle the face for 2 s before moving the face <b>down</b>. At the pause dot, stop, wiggle the face for 2 s, then keep the face still for 2 s and use end prompt.</p> 
<p><b>PROMPT</b></p>	<p><b>Verbal Prompt</b> Starting Prompt: "Peter (voice calling first) look, it is a animal/ baby". End Prompt: "Peter, bye-bye animal / baby".</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>Complete SPEM smoothly without being distracted and without head movement. Can maintain the eye position at the end ranges.</p>
<p><b>ATTEMPTS</b></p>	<p>One attempt.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b> Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

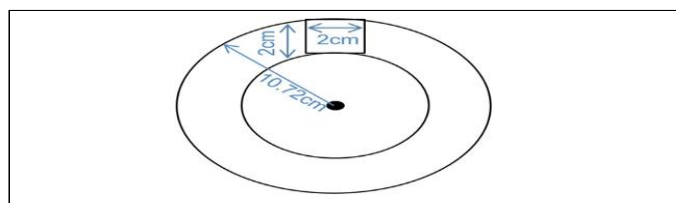

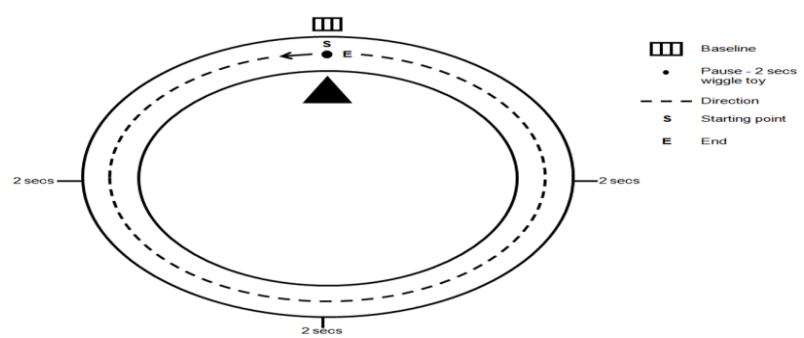
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<b>SCORING VERTICAL SPEM</b>		
<b>NOTE</b>		
<b>USE SPEM VERTICAL MEASUREMENT FOR SCORING 4 AND 5 OF MUSCLE BALANCE IN DIFFERENT DIRECTIONS (ITEM 7)</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Completes smoothly without being distracted. Only eye movement. No head movement.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Completes with large movement of head. Intermittent distraction.
<b>INEFFICIENT</b>	<b>0</b>	Cannot complete the movement. No attempt to follow. Not successful with the first and only attempt.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**13. SMOOTH PURSUIT EYE MOVEMENT CIRCULAR CLOCKWISE (SPEM)**

Smooth pursuit eye movements refer to smooth tracking movements by the eyes alone allowing the eyes to maintain foveal alignment with a moving target that is voluntarily selected against a stationary background. The purpose of SPEM is to stabilize moving objects on the retina and thereby enable the perception of object details.

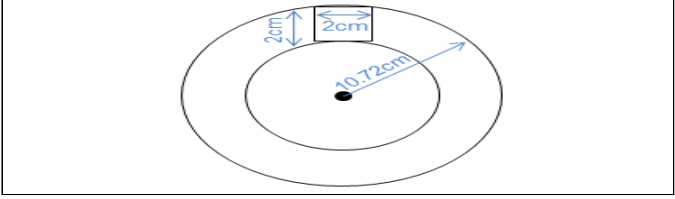

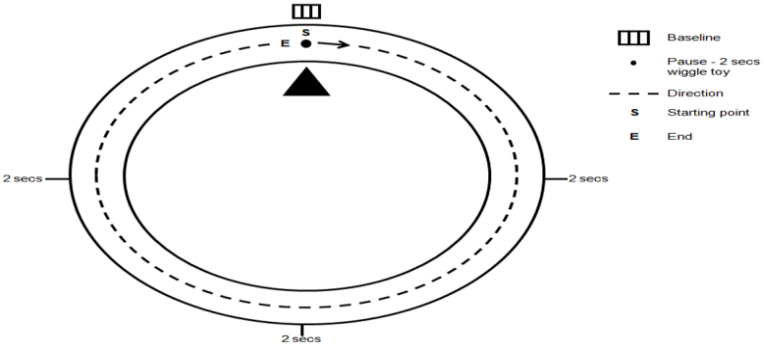
<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Animal toy. Circular SPEM stimulus card, mounted on base. <b>Note:</b> Clockwise for infant (anti-clockwise for administrator).</p>  <p><b>Positioning</b> Infant sits on the PCG's lap with support. Place the circular stimulus card on the platform.</p>
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES.</b></p>  <p><b>Directional/Movement</b> Place the toy at S for start, use starting verbal prompt. Wiggle toy for 2 s. Stop for 2 s, then move to the end by using the markers for the speed at the back of stimulus card. At the end (E) stop and use end verbal prompt.</p>  <ul style="list-style-type: none"> <li>▯▯▯ Baseline</li> <li>• Pause - 2 secs wiggle toy</li> <li>- - - Direction</li> <li>S Starting point</li> <li>E End</li> </ul>
<p><b>PROMPT</b></p>	<p><b>Verbal Prompt</b> Starting Prompt: "Peter (voice calling first) look, it is a animal". End Prompt: "Peter, bye-bye animal".</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>Complete SPEM smoothly without being distracted and without head movement.</p>
<p><b>ATTEMPTS</b></p>	<p>One attempt.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b> Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING</b>		
<b>CIRCULAR CLOCKWISE SPEM</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Completes smoothly without being distracted. Only eye movement. No head movement.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Completes with large movement of head. Intermittent distraction.
<b>INEFFICIENT</b>	<b>0</b>	Cannot complete the movement. No attempt to follow. Not successful with the first and only attempt.

**14. SMOOTH PURSUIT EYE MOVEMENT CIRCULAR ANTI-CLOCKWISE (SPEM)**

Smooth pursuit eye movements refer to smooth tracking movements by the eyes alone allowing the eyes to maintain foveal alignment with a moving target that is voluntarily selected against a stationary background. The purpose of SPEM is to stabilize moving objects on the retina and thereby enable the perception of object details.

<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Animal toy. Circular SPEM stimulus card, mounted on base.</p>  <p><b>Positioning</b> Infant sits on the PCG's lap with support. Place the circular stimulus card on the platform. <b>Note:</b> Anti-clockwise for infant ( clockwise for administrator).</p>
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p>  <p><b>Directional/Movement</b> Place the toy at S for start, use starting verbal prompt Wiggle toy for 2 s. Stop for 2 s, then move to the end by using the markers for the speed at the back of stimulus card. At the end (E) stop and use end prompt.</p> 
<p><b>PROMPT</b></p>	<p><b>Verbal Prompt</b> Starting Prompt: "Peter (voice calling first) look, it is a animal". End Prompt: "Peter, bye-bye animal".</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>Complete SPEM smoothly without being distracted and without head movement.</p>
<p><b>ATTEMPTS</b></p>	<p>One attempt.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b> Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

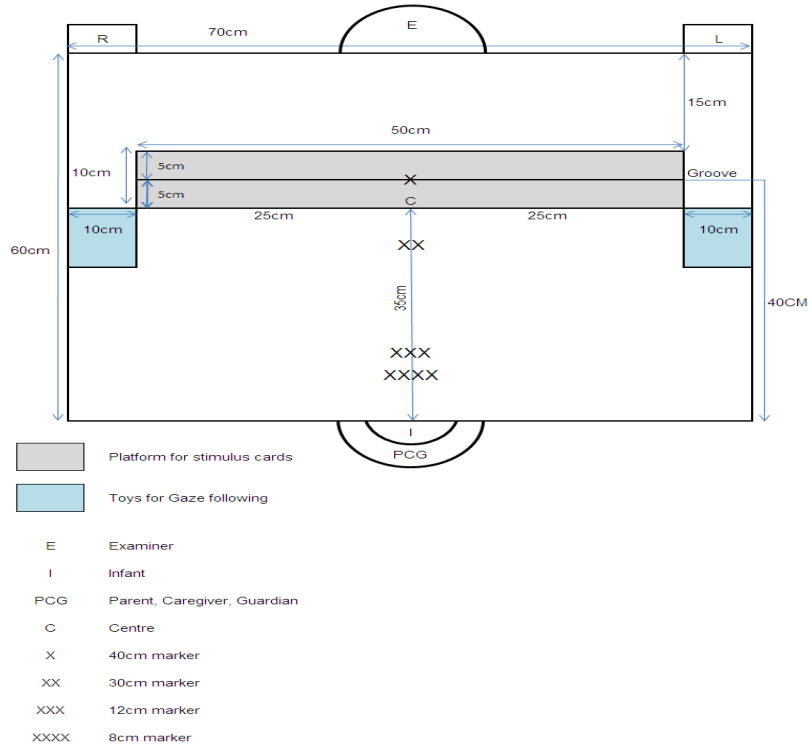
Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING</b>		
<b>CIRCULAR ANTI-CLOCKWISE SPEM</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Completes smoothly without being distracted. Only eye movement. No head movement.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Completes with large movement of head. Intermittent distraction.
<b>INEFFICIENT</b>	<b>0</b>	Cannot complete the movement. No attempt to follow. Not successful with the first and only attempt.

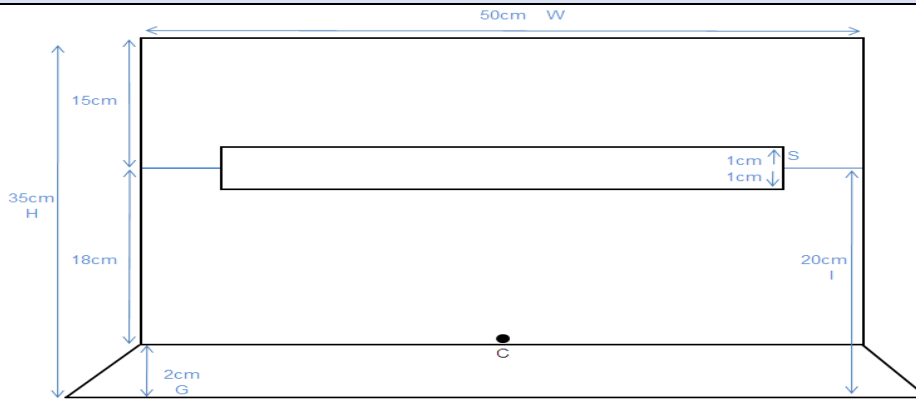
E. GAZE SHIFTING:GAZE PURSUIT (GP)

SCORE	CRITERIA FOR SCORING ITEMS
Item 15	Gaze pursuit from infant's left to right
Item 16	Gaze pursuit from infant's right to left

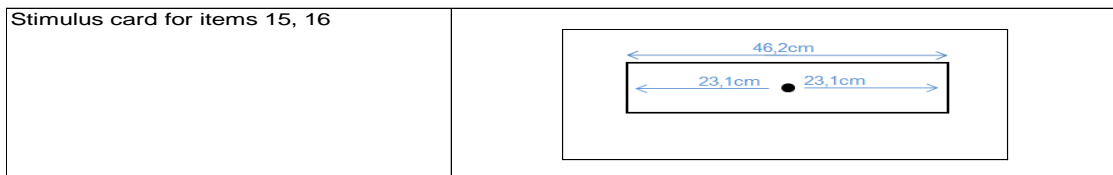
**G.14: Floor plan for items 15, 16**



**G.15: Platform for stimulus cards 15 and 16**



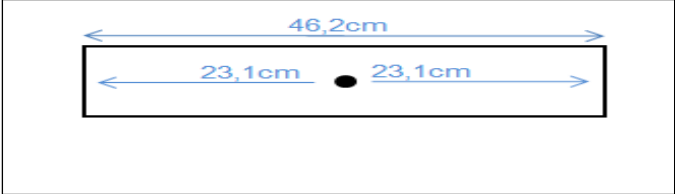
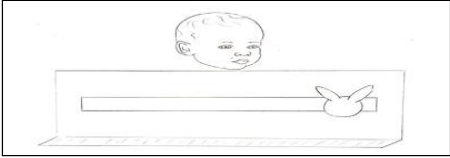
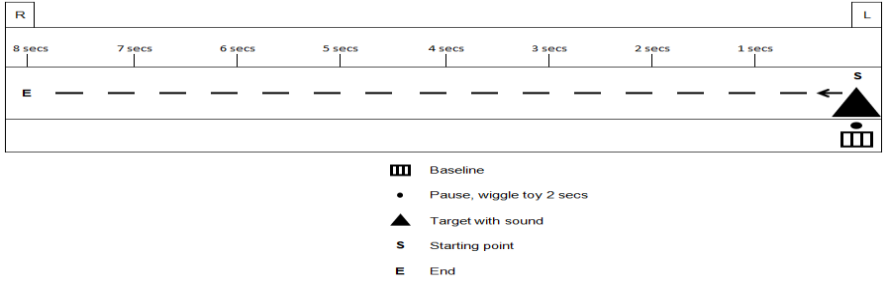
- Centre
- H Height = 35cm
- W Width = 50cm
- G 2cm in groove
- S Size of opening of slit 2cm
- I The middle of the slit is the same as the level of the infants eye - 20cm



Voluntary Eye Movement Measurement Tool  
(VEMMT)

**15. GAZE PURSUIT FROM INFANT'S LEFT TO RIGHT**

Gaze pursuit (GP) is when an infant visually tracks a smoothly moving target using a combination of eye and head movements to stabilize the retinal image of a moving target against a stationary background.

<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Fixation Stick marked GP 1 with sound. Large horizontal GP slit, mounted on base.</p>  <p><b>Positioning</b> Infant sits on the PCG's lap with support. Place the large horizontal stimulus card on the platform.</p>
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES STARTS IN THE PERIPHERAL VISUAL FIELD</b></p>  <p><b>Directional/Movement</b> Place the toy at the <b>S</b> for start in the peripheral visual field (left-side of infant) and use verbal prompt. Wiggle toy for 2 s at the starting point. Stop for 2 s. Wiggle again toy for 2 s and follow the speed as indicated on stimulus board. Do not wiggle toy during movement. No sound during movement. Stop at end and use end prompt.</p> 
<p><b>PROMPT</b></p>	<p><b>Verbal Prompt</b> Starting Prompt: "Peter (voice calling first) look". End Prompt: "Peter, bye-bye".</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>With attention grabbing stimulus, head turn and eye movement directly to the left and track smoothly to the end.</p>
<p><b>ATTEMPTS</b></p>	<p>One attempt.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b> Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

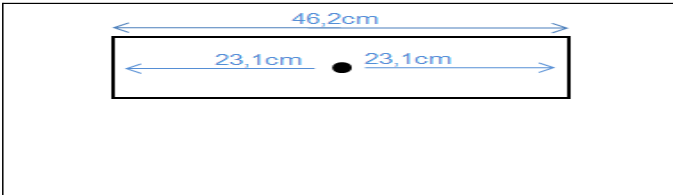
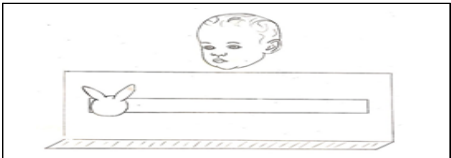
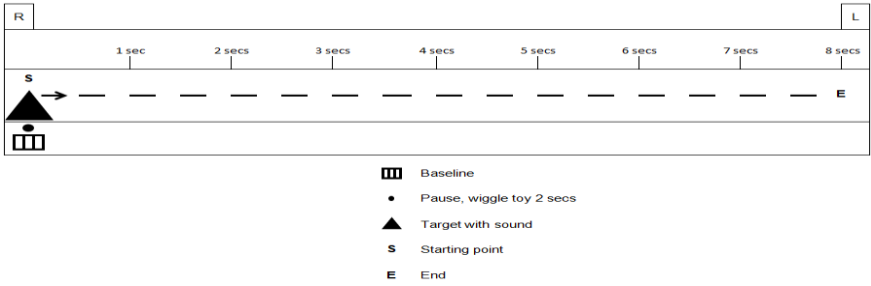
Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING</b>		
<b>GAZE PURSUIT FROM LEFT TO RIGHT</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Head turn and eye movement directly and immediately to the left and track smoothly to the end.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Refixations with large under- or overshooting the target.
<b>INEFFICIENT</b>	<b>0</b>	Cannot complete the movement. No attempt to turn to the target and follow. Not successful with the first and only attempt.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**16. GAZE PURSUIT FROM INFANT'S RIGHT TO LEFT**

Gaze pursuit (GP) is when an infant visually tracks a smoothly moving target using a combination of eye and head movements to stabilize the retinal image of a moving target against a stationary background.

<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Fixation stick marked GP2. Horizontal opening card with a wide slit.</p>  <p><b>Positioning</b> Infant sits on the PCG's lap with support. Place the large horizontal stimulus card on the platform</p>
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES STARTS IN THE PERIPHERAL VISUAL FIELD</b></p>  <p><b>Directional/Movement</b></p> <p>Place the toy at the <b>S</b> for start in the periheral visual field (right-side of infant) and use verbal prompt. Wiggle toy for 2 s at the starting point. Stop for 2 s. Wiggle again toy for 2 s and follow the speed as indicated on stimulus board. Do not wiggle toy during movement. No sound during movement. Stop at end and use end prompt.</p> 
<p><b>PROMPT</b></p>	<p><b>Verbal Prompt</b> Starting Prompt: "Peter (voice calling first) look". End Prompt: "Peter, bye-bye".</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>After the attention grabbing stimulus a head turn and eye movement directly to the right and track smoothly to the end.</p>
<p><b>ATTEMPTS</b></p>	<p>One attempt.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

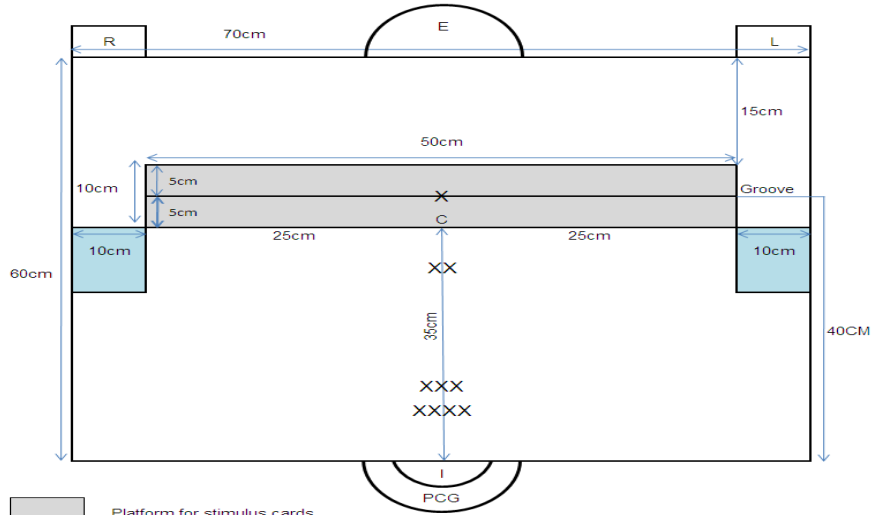
Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING</b>		
<b>GAZE PURSUIT FROM RIGHT TO LEFT</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Head turn and eye movement directly and immediately to the right and track smoothly to the end
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Refixations with large under- or overshooting the target.
<b>INEFFICIENT</b>	<b>0</b>	Cannot complete the movement. No attempt to turn to the target and follow. Not successful with the first and only attempt.

F. GAZE SHIFT: SACCADES

<b>Item 17</b>	Fixation shift paradigm
<b>Item 18</b>	Gap shift paradigm
<b>Item 19</b>	Express saccades
<b>Item 20</b>	Pupillary response
<b>Item 21</b>	Exogenous saccades/ blink response

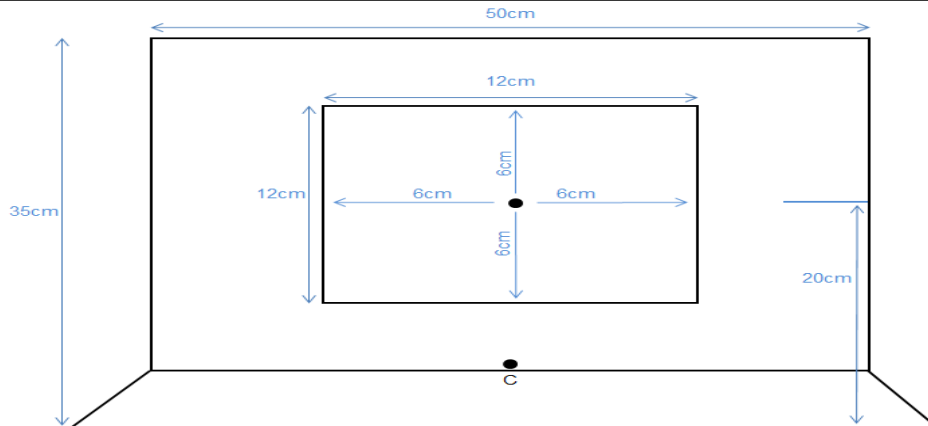
**G.16: Floor plan for items 17, 18, 19, 20 and 21**



- Platform for stimulus cards
- Toys for Gaze following

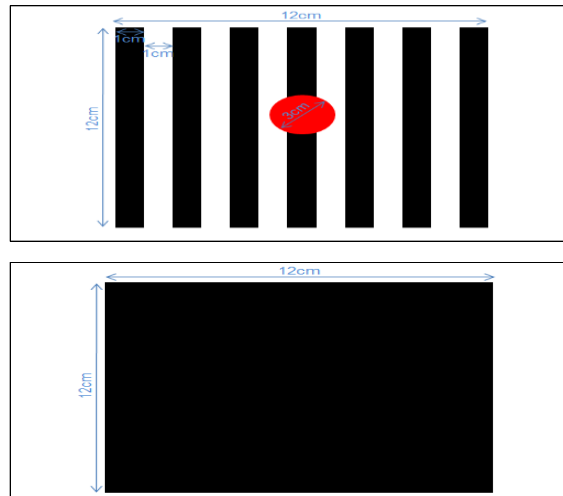
- E Examiner
- I Infant
- PCG Parent, Caregiver, Guardian
- C Centre
- X 40cm marker
- XX 30cm marker
- XXX 12cm marker
- XXXX 8cm marker

**G.17: Platform for item 17: Fixation shift paradigm**

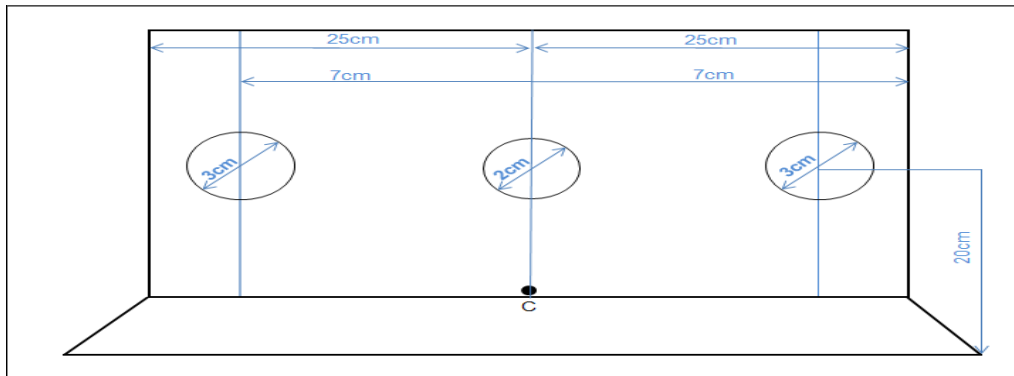


**G.18: Stimulus cards for items 17: Fixation shift paradigm**

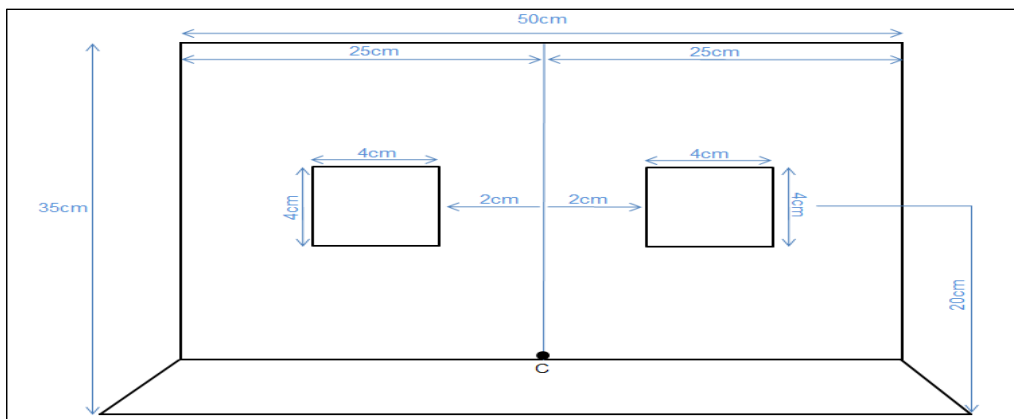
Fixation shift paradigm sliding stimulus cards.



**G.19: Platform and stimulus card for item 18: Gap shift paradigm**



**G.20: Platform and stimulus card for item 19: Express saccades**



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(VEMMT)

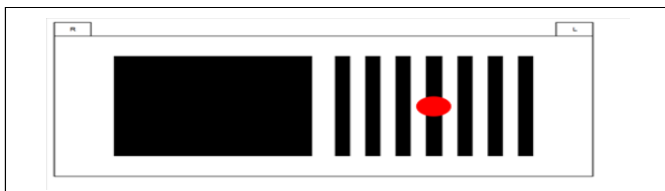
**17. FIXATION SHIFT PARADIGM (FSP)/COMPETITION CONDITION**

Saccades are rapid conjugate eye movements that shift the line of sight between successive points of fixation so that the point of interest will be seen with the foveal centre of the retina.

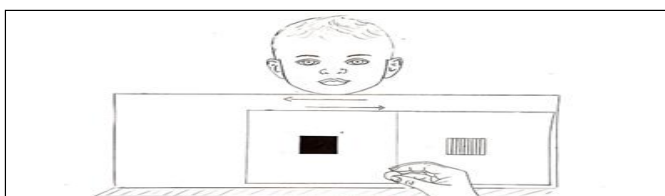
Fixation shift paradigm occurs under competition conditions. The central stimulus remains visible. In a FSP task infants are initially shown one stimulus in the centre. When the infant fixates on the central stimulus, a second target appears in the periphery. Switching attention under competition involves disengaging from the current stimulus, followed by a shift of attention, monitored as a saccadic gaze shift eye movement to the new target.

**EQUIPMENT**

**Toy**  
Stimulus card that is divided into two sections. A black/white striped picture with a red dot, the central stimulus, and a plain black picture.



**Positioning**  
Infant sits on the PCG's lap with support.



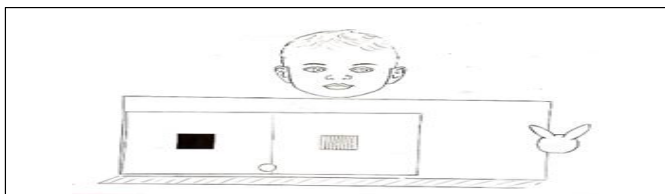
**PROCEDURE**

**APPLY THE BASELINE PRINCIPLES**

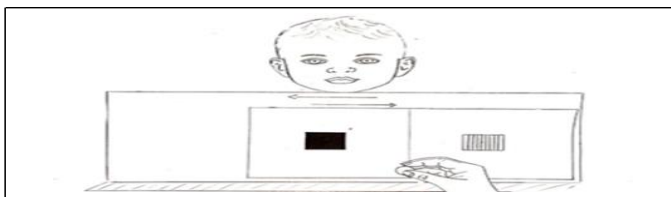
**1. Target appears on the infant's left side**  
Place the FSP stimulus card on the platform with the black picture visible for the infant in the center.  
Tap on the back of the stimulus card for 2 s (non-verbal prompt).  
Slide the black picture to the infant's right side and the black/white striped with the red dot picture is visible for infant.



As infant fixates on the stripe target a peripheral target appears on the infant's left, while the central stimulus remains visible.



**2. Target appears on the infant's right side**  
Slide the black picture to the center.



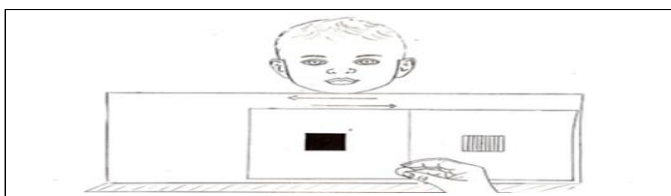
Tap on the back of the stimulus card for 2 s (non-verbal prompt).  
Slide the black picture again to the infant's right side and the black/white stripe picture with the red dot is visible for infant.



As the infant fixates on the stripe target a peripheral target appears on the infant's right, while the central stimulus remains visible.



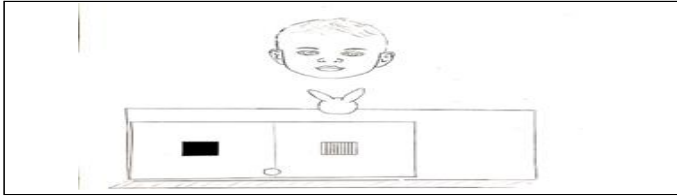
**3. Target appears above the platform**  
Slide the black picture to the center.



Tap on the back of the stimulus card for 2 s (non-verbal prompt).  
Slide the black picture again to the infant's right side and the black/white stripe picture with a red dot is visible for infant.



Voluntary Eye Movement Measurement Tool  
(VEMMT)

	<p>As the infant fixates on the stripe target a peripheral target appears above the stimulus card, while the central stimulus remains visible.</p> 
<b>PROMPT</b>	<p><b>Non-verbal</b> Tap on the back of the stimulus card for 2 s.</p>
<b>OUTCOME CRITERIA</b>	<p>Infant engages with non-verbal prompt, disengages from central stripe card and shifts gaze and head movement with a saccadic eye movement with attention immediately to the presented target.</p>
<b>ATTEMPTS</b>	<p>One attempt to each side. If infant does not engage to the stripe stimulus tap more than 2 s. If infant does not shift the gaze and attention to the presented target immediately, wiggle the target to attract the infant's attention for a saccadic eye movement.</p>
<b>BREAK</b>	<p style="text-align: center;"><b>“BREAKTIME”</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

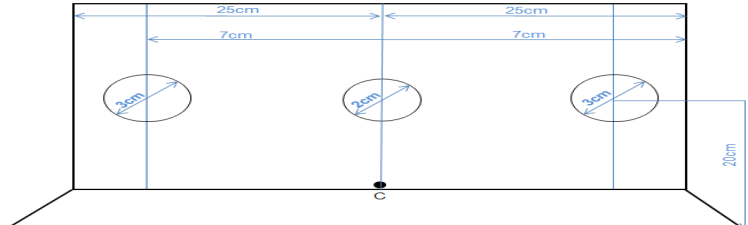
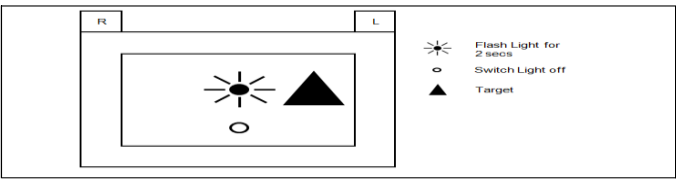
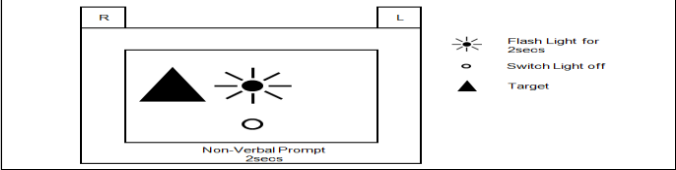
Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING</b>		
<b>FIXATION SHIFT PARADIGM/COMPETITION CONDITION</b>		
<b>EACH DIRECTION IS SCORED SEPERATELY ON SCORING FORM</b>		
<b>SCORE</b>	<b>CRITERIA FOR SCORING ITEMS</b>	
<b>EFFICIENTLY</b>	<b>2</b>	Infant engages and disengages from central stripe card and shifts gaze with a saccadic eye movement with attention immediately to the presented target.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Delay in response. Need to tap on board for more than 2 s for engagement or need to wiggle the target for disengagement and for saccadic gaze shifting.
<b>INEFFICIENT</b>	<b>0</b>	No attempt to engage, disengage and to shift gaze and attention to the presented toy.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**18. GAP SHIFT PARADIGM (GSP)**

The gap shift paradigm demonstrates the interaction between covert attentional processes and saccadic control. The reaction time to make a saccade to a peripheral target is significantly faster when a central fixation point goes off, shortly before another target is presented (gap).

<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Penlight. Small target</p> <p><b>Positioning</b> Infant sits on the PCG's lap with support. Mount the GSP stimulus card on the platform.</p> 
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p>Place and keep the flashlight in the center opening.</p> <p><b>1. Target to the infant's left</b> Tap on the back of the stimulus card for 2 s. Switch the center light on. Use the verbal prompt. Flash the light for 2 s. Switch light off. Present the target in the opening, on the infant's left. Keep target still for 2 s. Remove the light and target.</p>  <p><b>2. Target to the infant's right</b> Place and keep the flashlight in the center opening. Tap on the back of the stimulus card for 2 s. Switch the center light on. Use the verbal prompt. Flash the light for 2 s. Switch light off. Present the target in the opening, on the infant's right. Keep target still for 2 s. Remove the light and target</p> 
<p><b>PROMPT</b></p>	<p><b>Non-Verbal Prompt</b> Tapping on the back of the stimulus card for 2 s that is mounted on platform. <b>Verbal Prompt</b> "Peter look, it is a light".</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>Infant disengages from central light and shifts gaze with a saccadic eye movement with attention immediately to the presented target.</p>
<p><b>ATTEMPTS</b></p>	<p>One attempt to each side. If infant does not engage to the light, flash it for 5 s. If infant does not shift the gaze and attention to the presented target immediately, wiggle the target to attract the infant's attention for a saccadic eye movement.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

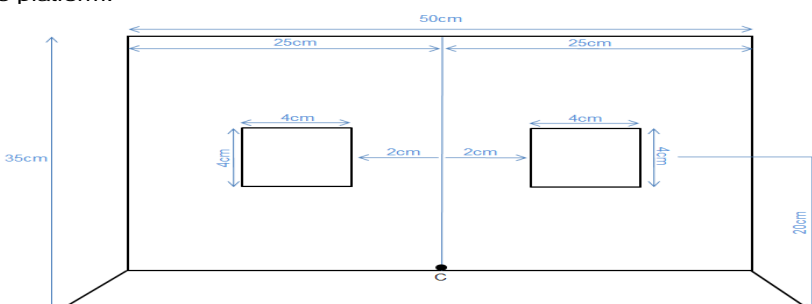
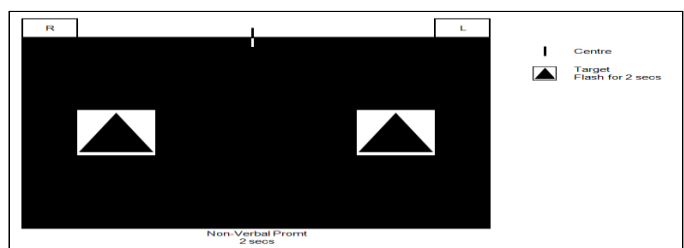
Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING GAP SHIFT PARADIGM EACH DIRECTION IS SCORED SEPERATELY</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Infant disengages from central light and shifts gaze with a saccadic eye movement with attention immediately to the presented target.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Delayed need to flash the light for longer than 2 s for engagement and need to wiggle the target to disengage from light and to shift gaze to the target.
<b>INEFFICIENT</b>	<b>0</b>	No attempt to engage, disengage and to shift gaze and attention to the presented toy.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**19. EXPRESS SACCADES**

Express saccades occur from central into peripheral visual field to foveate an object of interest.

<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Two penlights with coloured caps. <b>Positioning</b> Infant sits on the PCG's lap with support. Mount the express stimulus card on the platform.</p> 
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p>Place and keep the flashlights in the openings.</p> <p>Flash both lights (non-verbal prompt) until the infant focusses on the flashlights.</p> <p>Start with the light on the infant's left side / examiner's right side.</p> <p>Flash in the right window of examiner; left side of infant, for 2 s, stop.</p> <p>Flash in the left window of examiner, right side of infant for 2 s, stop.</p> <p>Complete 3 rounds.</p> <p style="text-align: center;">Order is R/L, R/L, R/L (right side of examiner)</p> 
<p><b>PROMPT</b></p>	<p><b>Non-Verbal Prompt</b> Flash both lights for attention getting.</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>Completes three round trips without head movement.</p>
<p><b>ATTEMPTS</b></p>	<p>One attempt.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>“BREAKTIME”</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

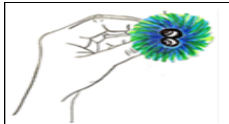



Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING EXPRESS SACCADES</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Completes three round trips without head movement. No over-or undershooting (Fixates accurately on the stimulus) Accurately and consistently fixating on the flashing light.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Completes three rounds with head movement. Large over and undershooting (Cannot accurately fixates on the target).
<b>INEFFICIENT</b>	<b>0</b>	Not successful. Disengage during measurement. Passive staring/ gluing on one flashing light and ignore the other stimulus.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**20. PUPILLARY REACTIONS TO LIGHT**

A light shone into an eye produces an immediate pupil constriction in that eye and an indirect pupil constriction in the other eye, so called a consensual response. The pupillary response, an innate reflex, is clinical important in localizing lesions involving the optic efferent and afferent pathways.

<p><b>EQUIPMENT</b></p>	<p><b>Toy</b> Bright penlight. <b>Distractor</b> Colourful distractor. <b>Positioning</b> Infant sits on the PCG's lap with support. Distance of distractor 30 cm in central visual field. Distance of light from pupil is 8 cm (Refer to floor plan).</p>
<p><b>PROCEDURE</b></p>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p><b>1. Infant's left eye's pupil response</b> Examiner holds the distractor in her/his left hand. Wiggle distractor for 2 s. Use verbal prompt.</p> <div style="text-align: center;">  </div> <p>As the infant fixates on the distractor toy, stop wiggling, and shine the light in infants <b>left pupil</b> bringing the light in from the temporal area. Keep it steady for 2 s.</p> <div style="text-align: center;">  </div> <p><b>2. Infant's right eye's pupil response</b> Examiner holds the distractor in her/his right-hand. Wiggle distractor for 2 s. Use verbal prompt.</p> <div style="text-align: center;">  </div> <p>As the infant fixates on the distractor toy, stop wiggling, and shine the light in infants <b>right pupil</b> bringing the light in from the temporal area. Keep it steady for 2 s.</p> <div style="text-align: center;">  </div>
<p><b>PROMPT</b></p>	<p><b>Verbal prompt</b> "Peter (first name calling), look, it is a pom-pom".</p>
<p><b>OUTCOME CRITERIA</b></p>	<p>The light shone into an pupil produce an immediate direct response, constriction of the pupil, in that eye and an immediate indirect consensual response in the other pupil.</p>
<p><b>ATTEMPTS</b></p>	<p>One attempt for each pupil.</p>
<p><b>BREAK</b></p>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

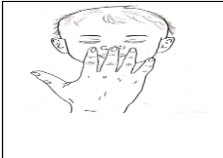
Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING PUPILLARY RESPONSE DIRECT OBSERVATION WITH IMMEDIATE SCORING</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	The infant keep fixation in the distance. Constriction of pupil with direct light and a consensual response in the other eye. Both pupils constrict simultaneously.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Constriction of pupil with direct and indirect stimulus but infant cannot tolerate the light for 2 s.
<b>INEFFICIENT</b>	<b>0</b>	No constriction in the direct and consensual response.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**21. EXOGENOUS GENERATED SACCADES WITH A BLINK RESPONSE**

Exogenous saccades are made to novel stimuli (visual, auditory, or tactile) that unexpectedly occur within the visual environment. Exogenous orienting usually involves salient objects that appear suddenly in the visual field and capture attention with gaze shifting.

<b>EQUIPMENT</b>	<p><b>Toy</b> Bright hand puppet.</p> <p><b>Positioning</b> Infant sits on the PCG's lap with support.</p>
<b>PROCEDURE</b>	<p style="text-align: center;"><b>APPLY BASELINE PRINCIPLES</b></p> <p>Hide the hand puppet under the table. Place it suddenly in the central visual field in front of the infant at a distance of 30 cm from the face of the infant. Use verbal prompt. Wiggle hand puppet for 2 s. Move quickly to the infant's face. Stop at 8 cm from face.</p> <div style="text-align: center;">  </div>
<b>PROMPT</b>	<p><b>Verbal Prompt</b> "Peter (name calling first), look!"</p>
<b>OUTCOME CRITERIA</b>	<p>Captured attention with a gaze shift, saccadic eye movement, by the sudden appearance of object in the central visual field. Immediate defensive blink to the target in the central field.</p>
<b>ATTEMPTS</b>	<p>One attempt.</p>
<b>BREAK</b>	<p style="text-align: center;"><b>"BREAKTIME"</b></p> <p>Caregiver can console the infant if needed. Clinician sets up equipment for the next measurement.</p>

Voluntary Eye Movement Measurement Tool  
(VEMMT)

<b>SCORING</b>		
<b>EXOGENOUS GENERATED SACCADIC GAZE WITH A BLINK RESPONSE</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Captured attention with a gaze shift, saccadic eye movement, by the sudden appearance of object in the central visual field. Immediate defensive blink to the target in the central field.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Delay in immediate attention with a saccadic gaze shift to the hand puppet. Delayed blink response.
<b>INEFFICIENT</b>	<b>0</b>	Homolateral blink or absent. No capturing of attention and gaze saccadic shift. Not successful with the first and only attempt.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**22. ATTENTION: DISENGAGEMENT**

Disengagement assists the infant to shift attention to something new. An infant will turn away from the stimulus in a consistent manner for e.g., look down when finishing with the attention holding.

<b>SCORING ATTENTION DISENGAGEMENT</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Direct gaze from an attended target to another presented target in the CVF or PVF with ease.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Needs prompts to disengage.
<b>INEFFICIENT</b>	<b>0</b>	Sticky fixation and cannot engage to make a voluntary eye movement.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**23. ATTENTION: ATTENTION HOLDING**

Attention holding is the maintenance of a stimulus which is intricate or novel. It is reflected by how long the infant engages in cognitive activity involving a stimulus.

<b>SCORING ATTENTION HOLDING</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Infant inspects a toy when holding and shows a variety motor actions for manipulation.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Infant tends to look away when the object is being touched or when hold.
<b>INEFFICIENT</b>	<b>0</b>	No attempt to inspect the object even if the object is placed passively in the infant's hand.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**24. ATTENTION: ATTENTION GETTING**

Attention getting is considered the initial orientation or alerting to a stimulus and can be observed in head-turning or a gaze shift toward a large, bright object presented in the periphery and/or in the central visual field.

<b>SCORING ATTENTION GETTING</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Infant easily shift eye movements in a voluntary manner to attend to the examiner by making eye contact and shows an interest in the testing environment and objects.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Needs to be directed with prompts with minimal eye contact.
<b>INEFFICIENT</b>	<b>0</b>	Appears to be overwhelmed with the objects and environment and avoid eye contact or visual contact with the objects.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**25. ATTENTION: JOINT ATTENTION**

Joint attention (JA) refers to the infant's ability to follow the direction of the gaze or gesture of others to share a common point of reference.

<b>SCORING JOINT ATTENTION</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Initiates JA easily and share interest with another person.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	The infant's starts to initiate JA but loses interest easily in the object.
<b>INEFFICIENT</b>	<b>0</b>	Cannot initiate JA.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**26. ATTENTION: SUSTAINED ATTENTION AND SELF-REGULATION**

Sustained attention and self-regulation lie in the infant's capacity to direct and focus cognitive activity on specific stimuli while simultaneously regulating arousal and responses to sensory stimulation.

<b>SCORING</b>		
<b>SUSTAINED ATTENTION AND SELF-REGULATION</b>		
<b>SCORE</b>		<b>CRITERIA FOR SCORING ITEMS</b>
<b>EFFICIENTLY</b>	<b>2</b>	Shows sustained attention during novel visual, auditory and tactile stimuli while simultaneously regulating arousal levels.
<b>SOMEWHAT EFFICIENTLY</b>	<b>1</b>	Needs assistance from PCG for regulation. Need more time for consoling.
<b>INEFFICIENT</b>	<b>0</b>	Does not show an interest in the objects or environment and gets upset easily.

Voluntary Eye Movement Measurement Tool  
(VEMMT)

**LIST OF TABLES**

<b>Table</b>	<b>Description</b>	<b>Pages</b>
G.1	Domains and items	1
G.2	Rating scales: Criteria of the different rating scores	2
G.3	Interpretation of the results	2
G.4	Baseline principles	3

**LIST OF FIGURES**

<b>Figure</b>	<b>Description</b>	<b>Pages</b>
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G.3	Floor plan for item 3	4
G.4:	Floor plan for item 5	13
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G.10	Convergence stick and platform for item 10	20
G.11	Floor plan for items 11, 12, 13, and 14	30
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## APPENDIX H

**CLINICAL MEASUREMENT TOOL FOR MEASURING VOLUNTARY  
EYE MOVEMENTS IN TYPICAL INFANTS 6 MONTHS OF AGE  
VEMMT 6 MONTHS OF AGE**



Infants name/ Number \_\_\_\_\_  
 Parent / Caregiver/Guardian's name: \_\_\_\_\_  
 Tester name: \_\_\_\_\_  
 Discipline: \_\_\_\_\_

Gender 

M	F
---	---

Age of full term infant	VEMMT			
		<i>Year</i>	<i>Month</i>	<i>Day</i>
	Evaluation Date			
	Date of Birth			
	Chronological Age			

Age of premature infant	VEMMT			
		<i>Year</i>	<i>Month</i>	<i>Day</i>
	Evaluation Date			
	Date of Birth			
	Chronological Age			
Adjustmant Age				

Reason for Referral _____ _____ _____ _____ _____	Parent/Caregiver/Guardian Concerns _____ _____ _____ _____ _____
--	---

Voluntary Eye Movement Measurement Tool VEMMT				
Functional vision for participation - Near task work	<b>1. Look, reach, grasp, hold and release rattle with the right hand</b>			
			<b>Notes</b>	<b>Item Score</b>
	Look	2		
		1		
		0		
	Reach	2		
		1		
		0		
	Grasp	2		
		1		
		0		
	Hold	2		
		1		
		0		
	Release	2		
		1		
		0		
		Total item score: Look, reach, grasp, hold and release - Right hand		
	<b>2. Look, reach, grasp, hold and release rattle with the left hand</b>			
	Look	2		
		1		
		0		
	Reach	2		
		1		
		0		
	Grasp	2		
		1		
		0		
	Hold	2		
		1		
		0		
	Release	2		
		1		
		0		
		Total item score: Look, reach, grasp, hold and release - Left hand		
	<b>3. Looking, reaching, touching and holding a ball, with both hands to midline</b>			
	Look	2		
		1		
		0		
	Reach	2		
		1		
		0		
	Grasp	2		
		1		
		0		
	Hold	2		
		1		
		0		
	Release	2		
		1		
		0		
		Total item score: Look, reach, touch and hold a ball, with both hands		
	<b>4. Adaptive reach with tactile input</b>			
		2		
		1		
		0		
		Total item score: Adaptive reach with tactile input		
	<b>Total score for the sub-domain: Near Task work</b>			

Voluntary Eye Movement Measurement Tool VEMMT				
Functional vision for participation - Social interaction	<b>5. Peek a Boo</b>			
			<b>Notes</b>	<b>Item Score</b>
		2		
		1		
		0		
			Total item score: Peek a Boo	
	<b>6. Gaze following</b>			
	To the right	2		
		1		
		0		
To the left	2			
	1			
	0			
		Total item score: Gaze following		
<b>Total score for the sub-domain: Social Interaction</b>				
<b>Total score for the domain: Functional Vision For Participation</b>				

Voluntary Eye Movement Measurement Tool VEMMT						
Gaze Holding	<b>7. Muscle balance in different directions</b>					
			<b>Notes</b>	<b>Item Score</b>	<b>Sub Domain Score</b>	<b>Domain Score</b>
	1	2				
		1				
		0				
	2	2				
		1				
		0				
	3	2				
		1				
		0				
	4	2				
		1				
		0				
	5	2				
		1				
		0				
	6	2				
		1				
		0				
	7	2				
		1				
		0				
	8	2				
		1				
		0				
	9 Central	2				
		1				
		0				
			Total item score: Muscle balance in different directions			
	<b>8. Direct penlight reflection</b>					
		2				
		1				
		0				
			Total item score: Direct penlight reflection			
<b>9. Ocular alignment cover / uncover</b>						
	2					
	1					
	0					
		Total item score: Ocular alignment cover / uncover				
<b>10. Convergence</b>						
	2					
	1					
	0					
		Total item score: Convergence				
<b>Total score for the domain: Gaze Holding</b>						

Voluntary Eye Movement Measurement Tool VEMMT						
<b>Gaze shift - Smooth pursuit eye movement (SPEM)</b>	<b>11. Horizontal SPEM</b>					
			<b>Notes</b>	<b>Item Score</b>	<b>Sub Domain Score</b>	<b>Domain Score</b>
		2				
		1				
		0				
			Total item score: Horizontal SPEM			
	<b>12. Vertical SPEM</b>					
		2				
		1				
		0				
			Total item score: Vertical SPEM			
	<b>13. Circular clockwise SPEM</b>					
		2				
		1				
		0				
			Total item score: Circular clockwise SPEM			
<b>14. Circular anti-clockwise spem</b>						
	2					
	1					
	0					
		Total item score: Circular anti-clockwise SPEM				
<b>Total score for the sub-domain: Smooth pursuit eye movement (SPEM)</b>						

Voluntary Eye Movement Measurement Tool VEMMT						
<b>Gaze shift - Gaze pursuit (GP)</b>	<b>15. Gaze pursuit to the right</b>					
			<b>Notes</b>	<b>Item Score</b>	<b>Sub Domain Score</b>	<b>Domain Score</b>
		2				
		1				
		0				
			Total item score: Gaze pursuit to the right			
	<b>16. Gaze pursuit to the left</b>					
		2				
		1				
		0				
		Total item score: Gaze pursuit to the left				
<b>Total score for the sub-domain: Gaze pursuit (GP)</b>						

Voluntary Eye Movement Measurement Tool VEMMT						
<b>Gaze shift - Saccades</b>	<b>17. Fixation shift paradigm</b>					
			<b>Notes</b>	<b>Item Score</b>	<b>Sub Domain Score</b>	<b>Domain Score</b>
	To the left	2				
		1				
		0				
	To the right	2				
		1				
		0				
	To the top	2				
		1				
		0				
			Total item score: Fixation shift paradigm			
	<b>18. Gap shift paradigm</b>					
	To the left	2				
		1				
		0				
	To the right	2				
		1				
		0				
			Total item score: Gap shift paradigm			
	<b>19. Express saccades</b>					
	2					
	1					
	0					
		Total item score: Express saccades				
<b>20. Pupillary response</b>						
Left eye	2					
	1					
	0					
Right eye	2					
	1					
	0					
Consensual	2					
	1					
	0					
		Total item score: Pupillary response				
<b>21. Exogenous saccades blink response</b>						
Left eye	2					
	1					
	0					
		Total item score: Exogenous saccades blink response				
<b>Total score for the sub-domain: Saccades</b>						
<b>Total score for the domain: Gaze Shifting</b>						

Voluntary Eye Movement Measurement Tool VEMMT					
<b>Attention</b>	<b>22. Disengagement</b>				
	Definition: The ability to direct the fovea from an attended central or peripheral target to engage with another target in the visual fields. Disengaging from and shifting gaze to a salient stimulus is a prerequisite for early exploration, reaching, and communication.				
		2			
		1			
		0			
		Total item score: Disengagement			
	<b>23. Attention holding</b>				
	Definition: Attention holding is the maintenance of a stimulus which is intricate or novel. It is reflected by how long the infant engages in cognitive activity involving a stimulus.				
		2			
		1			
		0			
		Total item score: Attention holding			
	<b>24. Attention getting</b>				
	Definition: Attention-getting is considered the initial orientation or alerting to a stimulus and can be observed in head-turning or a gaze shift toward a large, bright object presented in the CFV or PVF.				
		2			
	1				
	0				
	Total item score: Attention getting				
<b>25. Joint attention</b>					
Definition: JA refers to the infant's ability to follow the direction of the gaze or gesture of others to share a common point of reference. Initiation and cycle of JA involve alternating looking by first looking at an object, making eye contact with another individual to share the attention of the object and then look at the object again.					
	2				
	1				
	0				
	Total item score: Joint attention (JA)				
<b>26. Sustained attention and self-regulation</b>					
Definition: The process of self-regulation involves the capacity to modulate mood, self-calm delay gratification and tolerated transitions of activities. Sustained attention is the ability to direct and focus cognitive activity on specific stimuli.					
	2				
	1				
	0				
	Total item score: Sustained attention and self-regulation				
<b>Total score for the domain: Attention</b>					
<b>VEMMT TOTAL SCORE</b>					

DOMAIN A: FUNCTIONAL VISION FOR PARTICIPATION	
Near task work	
Social interaction	
<b>Domain A: Total score</b>	

DOMAIN B: GAZE HOLDING	
<b>Domain B: Total score</b>	

DOMAIN C: GAZE SHIFTING	
Smooth pursuit (SPEM)	
Gaze pursuit (GP)	
Saccades	
<b>Domain C: Total score</b>	

DOMAIN D: ATTENTION	
<b>Domain D: Total score</b>	

VEMMT TOTAL SCORE	
DOMAIN A	
DOMAIN B	
DOMAIN C	
DOMAIN D	
<b>TOTAL SCORE FOR VEMMT</b>	

# APPENDIX I

<b>Voluntary Eye Movement Measurement Tool</b> <b>VEMMT</b> <b>INCLUSION CRITERIA</b>
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NR
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<b>1. Biographical information</b>
------------------------------------

	Expected parameters
Age range: 6-to-7-months	
Infants from 37 weeks to full term	
Normal birth weight (2,500 grams or above)	
No diagnoses of a disability/disease	
Alertness state 4	

<b>2. Covid testing</b>
-------------------------

Researcher and PCG	Results negative	YES	NO
--------------------	------------------	-----	----

<b>3. Ages and stages questionnaire</b>
---

Area	Cutoff	Total Score	0	5	10	15	20	25	30	35	40	45	50	55	60
Communication	29,65		○	○	○	○	○	○	○	○	○	○	○	○	○
Gross Motor	22,25		○	○	○	○	○	○	○	○	○	○	○	○	○
Fine Motor	25,14		○	○	○	○	○	○	○	○	○	○	○	○	○
Problem Solving	27,72		○	○	○	○	○	○	○	○	○	○	○	○	○
Personal Social	25,34		○	○	○	○	○	○	○	○	○	○	○	○	○

ASQ-3 Typical range	YES	NO
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**4. Visual acuity (VA)**

CY/CM	Distance	Conversion	Cycle per degree	Response
1,3	55 cm	20/470	1.3 cpd	
2,4	55 cm	20/260	2.4 cpd	
4,8	55 cm	20/130	4.7 cpd	

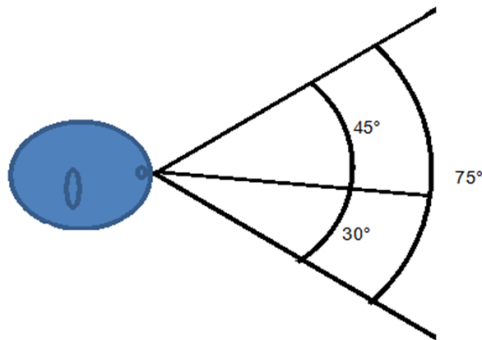
<b>VA Typical range</b>	<b>YES</b>	<b>NO</b>
-------------------------	------------	-----------

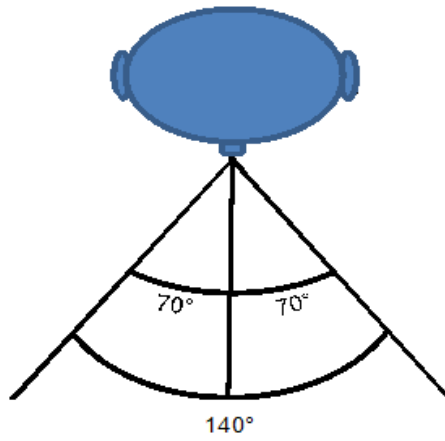
**5. Contrast sensitivity (CS)**

Contrast frequency	Distance	Response
Full contrast	55 cm	
25%	55 cm	
5%	55 cm	
1,25%	55 cm	

<b>CS Typical range</b>	<b>YES</b>	<b>NO</b>
-------------------------	------------	-----------

**6. Visual field (VF)**





VR	Range	Response
Upper	45°	
Lower	30°	
Right VF	70°	
Left VF	70°	

VR Typical range	YES	NO

INCLUDED IN RESEARCH PROJECT	YES	NO

## APPENDIX J

### TITLE OF STUDY: DEVELOPMENT OF A CLINICAL MEASUREMENT TOOL FOR MEASURING VOLUNTARY EYE MOVEMENTS IN TYPICAL INFANTS SIX MONTHS OF AGE VEMMT

**Dear Colleague**

Kindly complete Evaluation/Review form by the rating scale and make necessary recommendations on the comments section.

**Rating scale**

Scoring	Description	Meaning/action to be taken from
1	Completely irrelevant	Discard item/ replace item.
2	Minimal relevant	Unable to assess relevance, item revision is needed.
3	Very relevant	Need minor alterations.
4	Extremely relevant	No correction.

A. PURPOSE OF THE STUDY		
Item	Description	Score
1	Identified domains, sub-domains and items represents the typical infant between 6-to-7-months of	
2	Defined domains, sub-domains and measurable items are applicable for the VEMMT.	
3	The new developed VEMMT achieved its desired purpose.	
<b>Comments:</b>		

B. IDENTIFIABLE MEASURABLE CRITERIA		
Item	Description	Score
4	Content of the user administration manual is comprehensive and applicable for the VEMMT.	
5	General guidelines are clear and understandable.	
6	The set-up of room/equipment are well structured.	
7	Holistic parental guidelines (Posture of infant).	
8	Items represent eye movements for functional vision.	
9	Timeline for the administration is appropriate for the 6-to-7-months old infants.	
10	Flow and sequence of the domains, sub-domain and items.	
11	Selected toys are appropriate.	
12	Specifics of the measurements, placements of toys and stimulus cards.	
13	Illustrations well designed for the VEMMT (Path, placements and distance of the target).	
14	Criteria describes expected typical outcome.	
15	Prompts well defined and appropriate.	
16	Appropriateness of use of distractors and breaks.	
<b>Comments:</b>		

C. GUIDELINES FOR PROCEDURES		
Item	Description	Score
17	Items are clear and understandable.	
18	Semantics: Easy to read and formatted well.	
19	Rating scale is efficient.	
20	Criteria for scoring of items.	
21	Scoring form.	
<b>Comments:</b>		

**4. Additional Comments: Kindly provide any additional comments in section below**

Thank you for participating

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# APPENDIX K

## AGES AND STAGES QUESTIONNAIRE-3

ASQ is a developmental and behavioural screening tools that are completed by parents or others familiar with the child about a child's development from ages 1 to 66. To score a questionnaire, the PCG's responses-yes (10 points), sometimes (5 points) and not yet (0 points) and are totalled for each development area. The five areas are then compared with empirically derived cut-off points that are shown on bar graphs on the ASQ-3 Information Summary sheet. Infant's whose scores fall within the white area of the bar graph are considered to be developing appropriately and could continue with the VEMMT. Infants whose score fall within the light purple shaded monitoring zone may require specialise activities provided by the occupational therapist. If the infant's score falls within the darkly shaded portion of the bar graph in any developmental area, then further diagnostic paediatric assessment is recommended. A formula was used to adjust scores when item responses were missed. The following figures illustrate scores obtained for the initial ten infants, for each item, during administration of the ASQ-3.

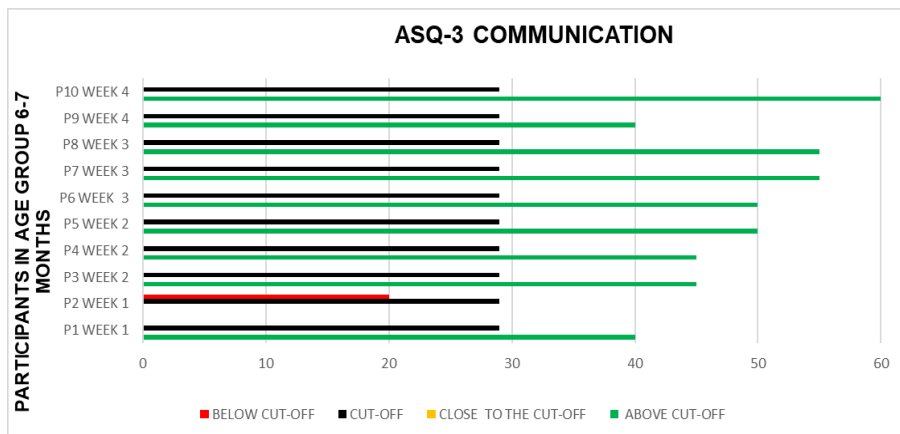


Figure K1: ASQ-3 communications scores

Figure K.1 illustrates the ASQ-3 communications scores. The graph illustrates that the communication score of one, aged 6-months 5 days of the ten participants scored below cut-off and was excluded from the study.

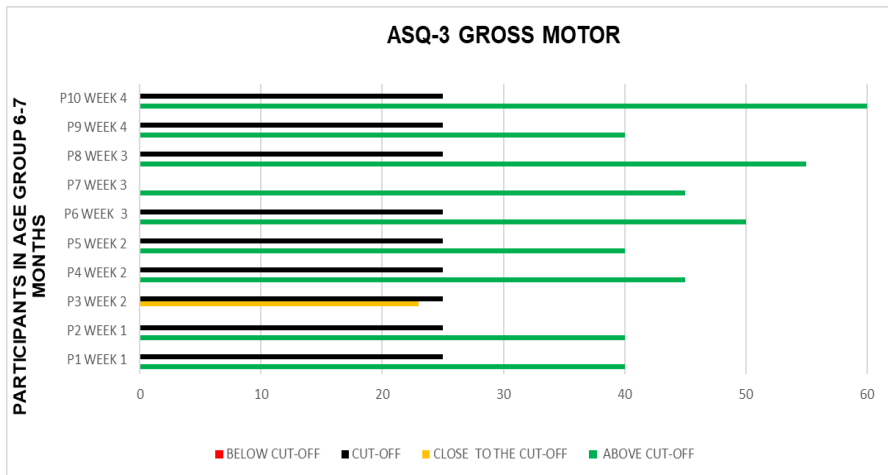


Figure K.2: ASQ-3 gross motor scores

Figure K.2 illustrates the ASQ-3 gross motor scores. The graph illustrates that the gross motor score of one participant, aged 6-months 8 days, was close to the cut-off and was excluded thus from the study.

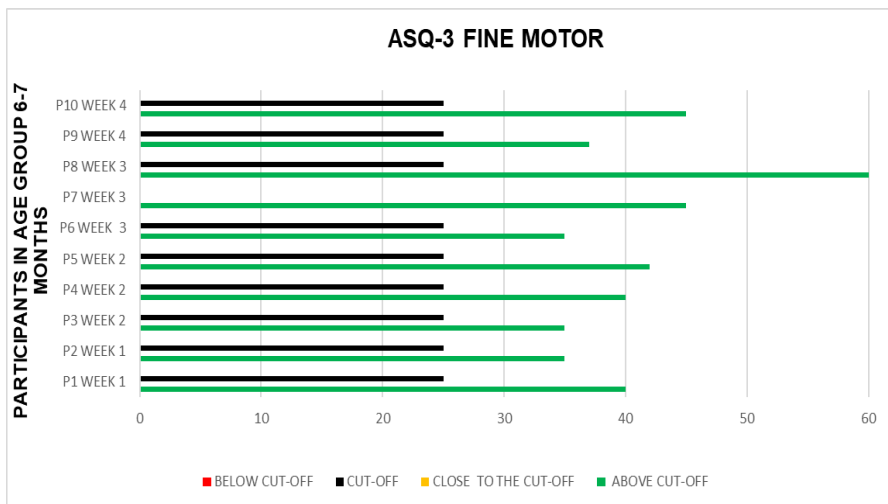


Figure K.3: ASQ-3 fine motor scores

Figure K.3 illustrates the ASQ-3 fine motor scores. The graph illustrates that all ten participants scored above the cut-off score for fine motor.

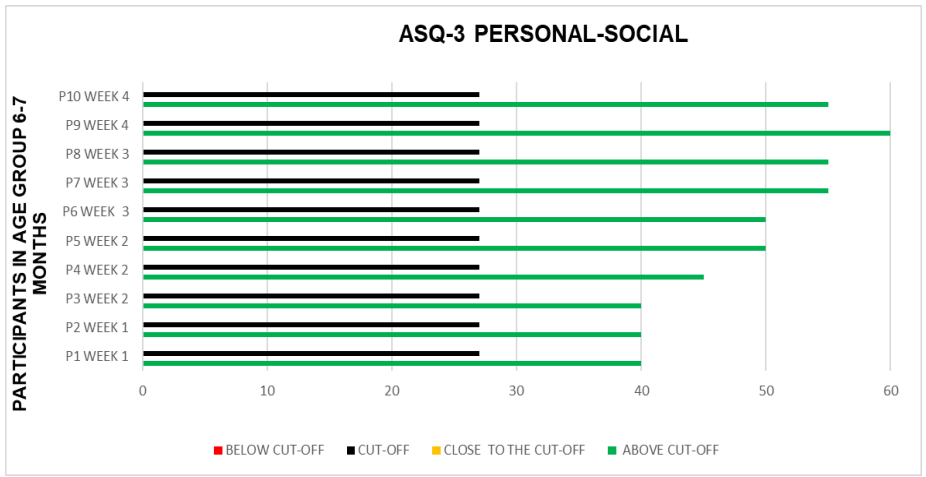


Figure K.4: ASQ-3 problem solving scores

Figure K.4 illustrates the ASQ-3 problem solving scores. The graph illustrates that the problem solving

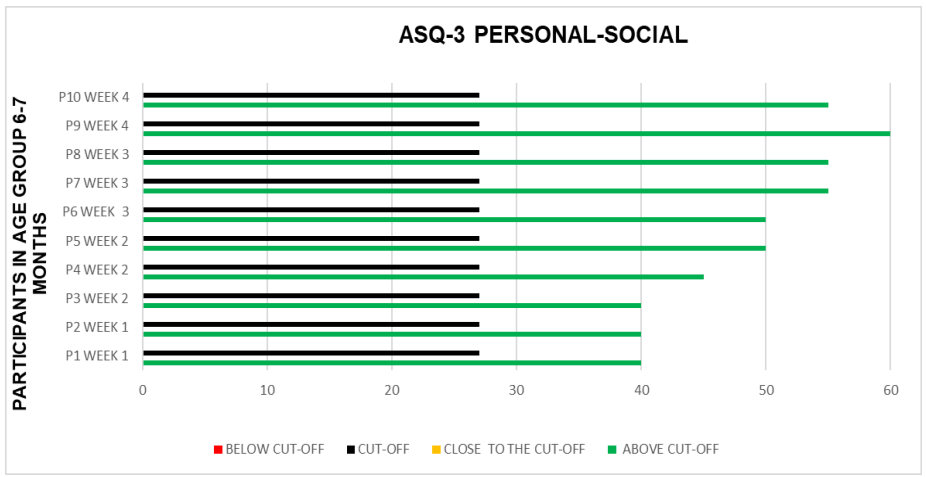


Figure K.5: ASQ-3 personal-social scores

Figure K.5 illustrates the ASQ-3 personal-social scores. The graph illustrates that the personal-social

# APPENDIX L

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## VEMMT: ITEM PROCEDURES AND PROMPTS

Domain	Items	Pages
A Functional vision for participation	1 - 6	pg 1-4
B Gaze holding	7 - 10	pg 5-7
C Gaze shift	11 - 21	pg 8-15

### WARM UP

PROCEDURES	
	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Tap on the back of the stimulus card until the infant focuses and <b>use:</b></p> <p><b>VP: "Peter, (name calling first), where is the rabbit?"</b></p> <p>As infant fixates on the board, a rabbit appears above and in the center of the board. Wiggle the rabbit for 5 s and <b>use:</b></p> <p><b>VP: "Peter, (name calling first) Hallo! Hallo!"</b></p> <p>Take the toy away and repeat the procedure for the left and right side.</p>

**DOMAIN A**  
**FUNCTIONAL VISION FOR PARTICIPATION**  
**ITEM 1 - 6**

**ITEM 1**  
**LOOK, REACH, GRASP, HOLD AND RELEASE RATTLE WITH THE INFANT'S**  
**RIGHT HAND**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Hide the rattle under the table.  Examiner holds it horizontal in her/his left hand.  Keep the right hand under the table with a distractor.</p> <p><b><i>Examiner is not allowed to look at the rattle, keep eye contact with the infant.</i></b></p> <p>Present the rattle horizontally from the infant's right midline and <b>use:</b></p> <p><b><i>NVP: Wiggle the rattle to make a sound.</i></b></p> <p>Use the marker on mat for placement of the rattle and <b>use:</b></p> <p><b><i>VP: "Peter (voice calling first), look, you can take it"</i></b></p> <p>Allow time for infant to play. Present a distractor with your right hand to release attention from rattle, to remove rattle after 10 s.</p>
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**ITEM 2**  
**LOOK, REACH, GRASP, HOLD AND RELEASE RATTLE WITH THE INFANT'S**  
**LEFT HAND**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Hide the rattle under the table.  Examiner holds it horizontal in his/her right hand.  Keep the left hand under the table with a distractor.</p> <p><b><i>Examiner is not allowed to look at the rattle, keep eye contact with the infant.</i></b></p> <p>Present the rattle horizontally from the infant's left midline and <b>use:</b></p> <p><b><i>NVP: Wiggle the rattle to make a sound</i></b></p> <p>Use the marker on the mat for placement of the rattle and <b>use:</b></p> <p><b><i>VP: "Peter (voice calling first), look, you can take it"</i></b></p> <p>Allow time for infant to play. Present a distractor with your left hand to release attention, to remove rattle to take rattle after 10 s.</p>
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**ITEM 3**  
**LOOK, REACH, GRASP/TOUCH, HOLD AND RELEASE A BALL, WITH BOTH HANDS.**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Hide the ball under the table.  The examiner does not look at the ball, she/he keeps eye contact with the infant.</p> <p>Present the ball in front and in the middle with both hands at the 12 cm marker and <b>use</b>:</p> <p><b>NVP: Wiggle the ball.</b></p> <p>Stop wiggling the ball and <b>use</b>:</p> <p><b>VP: “Peter (voice calling first), look, it is a ball, take it”</b></p> <p>Allow time for infant to play. Present a distractor to release attention from ball to remove the ball after 10 s.</p>
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**ITEM 4**  
**ADAPTIVE REACH WITH TACTILE INPUT.**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principle</b></p> <p>Ask the PCG to gently hold the infant’s arms in front.  Raise your eyebrow with a smile and show the tape.  Put the tape on your hand, cover it with your hand and play peek-a boo with the tape.</p> <p>Place the strip of tape with the red dot in the middle of the tape on the back of the infant’s left or right hand, leaving the ends free and <b>use</b>:</p> <p><b>VP: “Peter (voice calling first), look what I put on your hand, go get it”.</b></p> <p>Wait for 30 s.</p>
<b>REMOVAL OF TAPE</b>	<p>To remove the tape, present a distractor to the infant.  Remove the tape softly after 30 s if the infant cannot do so.  If removed by infant, ask for it and say, “I take it”.  Remove it from the infant before the infant has an attempt to put into the mouth.</p>

**ITEM 5  
PEEK-A-BOO**

<b>PROCEDURES</b>	<p align="center"><b>Apply the baseline principles</b></p> <p>Put your hands in front of your face and say and <b>use</b>:</p> <p><b>VP: “I am not here” for 2 s.</b></p> <div align="center">  </div> <p>Expose your face, hands next to your face and fingers expanded with a direct gaze, eyebrow lift and <b>use</b>:</p> <p><b>VP: “Baa-Baa”</b></p> <p><b>Keep smiling for 5 s.</b></p> <div align="center">  </div> <p>Hide your face again and repeat once more.</p>
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**ITEM 6 (A)  
GAZE FOLLOWING  
TO THE INFANT’S LEFT / EXAMINER’S RIGHT**

<b>PROCEDURES</b>	<p align="center"><b>Apply the baseline principles</b></p> <p>Place the toys on the markers and the examiner removes his/her hands from table. Examiner lowers her head and gaze down for 2 s.</p> <p>Keep gaze lowered but slightly lift the head and make rapid horizontal head shakes for 2 s (social and non-ostensive prompt).</p> <p>Examiner has direct gaze with the infant raises eyebrow and smiles for 2 s (social and non-ostensive prompt).</p> <p>Examiner turns his/her head and eyes to his/her <b>RIGHT</b>.</p> <p>Keep gaze at toy and say “Wow, look, hallo” for 5 s.</p> <p>Moves head and eyes back to the infant to reconnect and interact by smiling and talking until infant makes eye contact and is in a regulatory state.</p>
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**ITEM 6 (B)**  
**GAZE FOLLOWING**  
**TO THE INFANT'S RIGHT / EXAMINER'S LEFT**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Place the toys on the table and the examiner removes her/his hands from table.</p> <p>Examiner lowers her head and gaze for 2 s.</p> <p>Keep gaze lowered but slightly lift the head and make rapid horizontal head shakes for 2 s (social and non-ostensive prompt).</p> <p>Examiner has direct gaze with the infant raises eyebrow and smiles for 2 s (social and non-ostensive prompt).</p> <p>Examiner turns her head and eyes to her <b>LEFT</b>.</p> <p>Keep gaze at toy and say "Wow, look, hallo" for 5 s.</p> <p>Moves head and eyes back to the infant to reconnect and interact by smiling and talking until infant makes eye contact and is in a regulatory state.</p>
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**DOMAIN B  
GAZE HOLDING  
ITEM 7 - 10**

**ITEM 7(A)  
MUSCLE BALANCE IN DIFFERENT DIRECTIONS -S1  
DIRECTIONS 2/3**

<b>PROCEDURES</b>	<b>Apply the baseline principle</b>
	<p>Place the fixation face in the center point, <b>use:</b></p> <p><b>VP: “Peter, (voice calling first) look, it is a baby. The baby walks away”.</b></p> <p>At S1 wiggle the face for 2 s, then keep the face still for 2 s.</p> <p>Again, wiggle face for 2 s and follow the direction of S1.</p> <p>Move to point 2 without stops and follow the speed indicators. At point 2, the pause dot, stop, wiggle the face for 2 s, then keep the face still for 2 s.</p> <p>Again, wiggle the face for 2 s before moving the face to the bottom end to point 3.</p> <p>At the pause dot, stop, wiggle the face for 2 s, then keep the face still for 2 s and <b>use:</b></p> <p><b>VEP: “Peter, bye-bye</b></p>


**ITEM 7(B)  
MUSCLE BALANCE IN DIFFERENT DIRECTIONS -S2  
DIRECTIONS 7/8**

<b>PROCEDURES</b>	<b>Apply the baseline principle</b>
	<p>Place the fixation face (2) in the center point, <b>use:</b></p> <p><b>VP: “Peter, (voice calling first) look, it is a baby. The baby walks away”.</b></p> <p>At S2 wiggle the face for 2 s, then keep the face still for 2 s.</p> <p>Again, wiggle face for 2 s and follow the direction of S2.</p> <p>Move to point 7 without stops and follow the speed indicators. At point 7, the pause dot, stop, wiggle the face for 2 s, then keep the face still for 2 s.</p> <p>Again, wiggle the face for 2 s before moving the face to the bottom end, to point 8.</p> <p>At the pause dot, stop, wiggle the face for s, then keep the face still for 2 s and <b>use:</b></p> <p><b>VEP: “Peter, bye-bye</b></p>


**ITEM 8  
OCULAR ALIGNMENT/CORNEAL REFLECTION/DIRECT PENLIGHT  
REFLECTION MEASUREMENT**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Play opposite the nose bridge of infant in the center by wiggling the light and <b>use:</b></p> <p><b>VP: “Peter, (voice calling first) look at the light”.</b></p> <p>Wiggle the light softly and when the infant fixates, stop and shine the penlight in the middle of nose bridge of infant for 2 s.</p>
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**ITEM 9(A)  
OCULAR ALIGNMENT COVER/UNCOVER MEASUREMENT INFANT’S  
RIGHT EYE**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Play opposite the nose bridge of infant in the center by wiggling the light and <b>use:</b></p> <p><b>VP: “Peter (voice calling first) look, it is a light”</b></p> <p>Wiggle the light softly and when the infant fixates, stop and shine the light for 2 s in the middle of nose bridge of infant.</p> <p><b>Right eye cover/uncover</b> After 2 s the examiner covers with her/his left hand the <b>right eye</b> of infant for 2 s.</p> <p><b>Uncover the right eye</b> and observe the <b>right eye</b>. Both eyes should be looking at the target when uncover without movement.</p> <div style="text-align: center;">  </div>
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**ITEM 9(B)**  
**OCULAR ALIGNMENT COVER/UNCOVER MEASUREMENT INFANT'S**  
**LEFT EYE**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Place the light opposite the nose bridge of infant in the center by wiggling the light and <b>use:</b></p> <p><b>VP: "Peter (voice calling first) look, it is a light"</b></p> <p>Wiggle the light softly and when the infant fixates, stop and shine the penlight for 2 s in the middle of nose bridge of infant.</p> <p><b>Left eye cover/uncover</b>  After 2 s the examiner covers with <b>her/his right hand the left eye</b> of infant for 2 s.</p> <p>Uncover the <b>left eye</b> and observe the <b>left eye</b>. Both eyes should be looking at the target when uncover without movement.</p> <div style="text-align: center;">  </div>
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**ITEM 10**  
**CONVERGENCE**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Place the toy in the center and <b>use:</b></p> <p><b>VP: "Peter (voice calling first) look".</b></p> <p>Wiggle toy for 2 s, then keep the toy still for 2 s.</p> <p>Again, wiggle the toy for 2 s and follow the markers on the stick.</p> <p>Move the target at a speed of 1 cm for every 10 cms. It takes 3 s to reach the end, at the 12 cm marker on mat, stop and keep toy still for 2 s, <b>use:</b></p> <p><b>VP: "Peter, bye-bye"</b></p> <p>If infant loses interest during the movement, the examiner may wiggle the toy once or twice for completion of distance to assist with attention holding with fixation.</p>
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**DOMAIN C  
GAZE SHIFTING  
ITEM 11 - 21**

**ITEM 11  
HORIZONTAL SPEM / ANIMAL**

<b>PROCEDURES</b>	<b>Apply the baseline principles</b>  Place the toy at the S for start in the center of slit and <b>use:</b>  <b>VP: “Peter (voice calling first) look it is an animal”.</b>  Wiggle toy for 2 s and move to the infant’s left, (Right side of E), by using the markers for the speed at the back of stimulus card.  At the pause dot, stop, wiggle the toy for 2 s, then keep the toy still for 2 s.  Again, wiggle the toy for 2 s before moving the toy to the infant’s right, (Left side of E).  At the pause dot, stop, wiggle the toy for 2 s, then keep the toy still for 2 s.  Again, wiggle the toy for 2 s before moving the toy back to the center and <b>use:</b>
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**ITEM 11  
HORIZONTAL SPEM / FIXATION FACE  
SCORING ITEM 7 NR 1 AND 6**

<b>PROCEDURES</b>	<b>Apply the baseline principles</b>  Place the fixation face target at the S for start in the center of slit and <b>use:</b>  <b>VP: “Peter (voice calling first) look, it is baby”.</b>  Keep fixation face still for 2 s. Wiggle face for 2 s and move to the infant’s left (Right side of E), by using the markers for the speed at the back of stimulus card.  At the pause dot, stop, wiggle the face for 2 s, then keep the face still for 2 s.  Again, wiggle the face for 2 s before moving the face to the infant’s right (Left side of E), by using the markers for the speed at the back of stimulus card.  At the pause dot, stop, wiggle the face for 2 s, then keep the face still for 2 s and <b>use:</b>  <b>VP: “Peter, bye-bye baby</b>
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**ITEM 12**  
**VERTICAL SPEM**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Place the toy at the S for start in the center of slit and <b>use</b>:</p> <p><b>VP: “Peter (voice calling first) look, it is a animal”.</b></p> <p>Wiggle toy for 2 s and move <b>up</b> by using the markers for the speed at the back of stimulus card.</p> <p>At the pause dot, stop, wiggle the toy for 2 s, then keep the toy still for 2 s.</p> <p>Again, wiggle the toy for 2 s before moving the toy <b>down</b>.</p> <p>At the pause dot, stop, wiggle the toy for 2 s, then keep the toy still for 2 s.</p> <p>Again, wiggle the toy for 2 s before moving the toy back to the center, stop and <b>use</b>:</p> <p><b>VP: “Peter, bye-bye animal”.</b></p>
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**ITEM 12**  
**VERTICAL SPEM/ FIXATION FACE**  
**SCORING ITEM 7 NR 4 AND 5**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Place the fixation face target at the S for start in the center of slit and <b>use</b>:</p> <p><b>VP: “Peter (voice calling first) look, it is a baby”.</b></p> <p>Wiggle face for 2 s and move <b>up</b> by using the markers for the speed at the back of stimulus card.</p> <p>At the pause dot, stop, wiggle the face for 2 s, then keep the face still for 2 s.</p> <p>Again, wiggle the face for 2 s before moving the face <b>down</b>.</p> <p>At the pause dot, stop, wiggle the face for 2 s, then keep the face still for 2 s and <b>use</b>:</p> <p><b>VP: “Peter, bye-bye baby”.</b></p>
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**ITEM 13**  
**CIRCULAR CLOCKWISE SPEM FOR INFANT**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p><b>(Note: Clockwise for infant, anti-clockwise for administrator).</b> Place the toy at S for start and <b>use:</b></p> <div style="text-align: center;">  </div> <p><b>VP: “Peter (voice calling first) look, it is a animal”.</b></p> <p>Wiggle toy for 2 s.</p> <p>Stop for 2 s, then move to the end by using the markers for the speed at the back of stimulus card. At the end (E) stop and <b>use:</b></p> <p><b>VP: “Peter, bye-bye animal”.</b></p>
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**ITEM 14**  
**CIRCULAR ANTI-CLOCKWISE SPEM FOR INFANT**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>APPLY THE BASELINE PRINCIPLES</b></p> <p><b>(Note: Anti-clockwise for infant, clockwise for administrator).</b></p> <div style="text-align: center;">  </div> <p>Place the toy at S for start in the center of slit and use:</p> <p><b>VP: “Peter (voice calling first) look, it is a animal”.</b></p> <p>Wiggle toy for 2 s.</p> <p>Stop for 2 s, then move to the end by using the markers for the speed at the back of stimulus card.</p> <p>At the end (E) stop, and <b>use:</b></p>
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**ITEM 15**  
**GAZE PURSUIT FROM INFANT'S LEFT TO RIGHT**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Place the toy at the <b>S</b> for start in the peripheral visual field (Left side of infant) and <b>use</b>:</p> <p><b>VP: "Peter (voice calling first), look"</b></p> <p>Wiggle toy for 2 s at the starting point. Stop for 2 s.</p> <p>Wiggle again toy for 2 s and follow the speed as indicated on stimulus board.</p> <p>Do not wiggle toy during movement. No sound during movement. Stop at the end and <b>use</b>:</p>
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**ITEM 16**  
**GAZE PURSUIT FROM INFANT'S RIGHT TO LEFT**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Place the toy at the <b>S</b> for start in the peripheral visual field (Right side of infant) and <b>use</b>:</p> <p><b>VP: "Peter (voice calling first), look"</b></p> <p>Wiggle toy for 2 s at the starting point. Stop for 2 s.</p> <p>Wiggle again toy for 2 s and follow the speed as indicated on stimulus board.</p> <p>Do not wiggle toy during movement. No sound during movement. Stop at the end and <b>use</b>:</p>
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**ITEM 17 (A)**  
**FIXATION SHIFT PARADIGM (FSP). COMPETITION CONDITION**  
**TARGET APPEARS ON THE INFANT'S LEFT**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Place the stimulus card on the platform with the black picture visible for the infant in the center and <b>use:</b></p> <p><b><i>NVP: Tap on the back of the black card for 2 s.</i></b></p> <p>Slide the black picture to the infant's right side and the black/white striped with the red dot picture is visible for infant.</p> <p>As infant fixates on the stripe target a peripheral target appears on the <b>infant's left</b>, while the central stimulus remains visible.</p>
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**ITEM 17 (B)**  
**FIXATION SHIFT PARADIGM (FSP). COMPETITION CONDITION**  
**TARGET APPEARS ON THE INFANT'S RIGHT**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Slide the black picture to the center and <b>use:</b></p> <p><b><i>NVP: Tap on the back of the black card for 2 s.</i></b></p> <p>Slide the black picture again to the infant's right side and the black/white stripe picture with the red dot is visible for infant.</p> <p>As infant fixates on the stripe target a peripheral target appears on the <b>infant's right</b>, while the central stimulus remains visible.</p> <p>Slide the black picture to the center.</p>
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**ITEM 17 (C)**  
**FIXATION SHIFT PARADIGM (FSP). COMPETITION CONDITION**  
**TARGET APPEARS ABOVE THE STIMULUS BOARD**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Slide the black picture to the center and <b>use:</b></p> <p><b><i>NVP: Tap on the back of the black card for 2 s.</i></b></p> <p>Slide the black picture again to the infant's right side and the black/white stripe picture with the red dot is visible for infant.</p> <p>As infant fixates on the stripe target a peripheral target appears <b>above the stimulus card</b>, while the central stimulus remains visible.</p>
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**ITEM 18(A)  
GAP SHIFT PARADIGM (GSP)  
TARGET TO THE INFANT'S LEFT**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Place and keep the flashlight in the center opening. <b>Use:</b></p> <p><b>NVP: Tap on the back of the stimulus card for 2 s.</b></p> <p>Switch the center light on and <b>use:</b></p> <p><b>VP: "Peter look, it is a light"</b></p> <p>Flash the light for 2s. Switch light off.</p> <p>Present the target in the opening, on the infant's left. Keep target still for 2 s.</p>
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**ITEM 18 (B)  
GAP SHIFT PARADIGM (GSP)  
TARGET TO THE INFANT'S RIGHT**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Place and keep the flashlight in the center opening. <b>Use:</b></p> <p><b>NVP: Tap on the back of the stimulus card for 2 s.</b></p> <p>Switch the center light on and <b>use:</b></p> <p><b>VP: "Peter look, it is a light"</b></p> <p>Flash the light for 2 s. Switch light off.</p> <p>Present the target in the opening, on the infant's right. Keep target still for 2 s.</p> <p>Remove the light and target.</p>
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**ITEM 19**  
**EXPRESS SACCADES**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Place and keep the flashlights in the openings and <b>use</b>:</p> <p><b>NVP: Flash both lights (non-verbal prompt) until the infant focusses on the flashlights.</b></p> <p>Start with the light on the infant's left side.</p> <p>Flash on the left side in window for 2 s, stop.</p> <p>Flash on the right side in window for 2 s, stop.</p> <p style="text-align: center;">Complete 3 rounds. Order is L/R; L/R and L/R</p>
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**ITEM 20 (A)**  
**PUPILLARY REACTION TO LIGHT**  
**INFANT'S LEFT PUPIL**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Examiner holds the distractor in her/his left-hand. Wiggle for 2 s and <b>use</b>:</p> <p><b>VP: "Peter (first name calling), look, it is a pom-pom".</b></p> <p>As the infant fixates on toy stop wiggling and shine the light in infant's left pupil bringing the light in from the temporal area.</p> <p>Keep it steady for 2 s.</p>
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**ITEM 20 (B)**  
**PUPILLARY REACTION TO LIGHT**  
**INFANT'S RIGHT PUPIL**

<b>PROCEDURES</b>	<p style="text-align: center;"><b>Apply the baseline principles</b></p> <p>Examiner holds the distractor in your left-hand. Wiggle for 2 s and <b>use</b>:</p> <p><b>VP: "Peter (first name calling), look, it is a pom-pom".</b></p> <p>As the infant fixates on toy, stop wiggling and shine the light in infant's right pupil bringing the light in from the temporal area.</p> <p>Keep it steady for 2 s.</p>
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**ITEM 21**  
**EXOGENOUS GENERATED SACCADES WITH A BLINK RESPONSE**

<b>PROCEDURES</b>	<b>Apply the baseline principles</b>  Hide the hand puppet under the table. Place it suddenly in the central visual field in front of the infant at a distance of 30 cm from the face of the infant and <b>use:</b>  <b><i>VP: "Peter (name calling first) look!"</i></b>  Wiggle hand puppet for 2 s and move quickly to the infant's face.  Stop at 8 cm from face.
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