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Exploring the dualism of vision – visual function and functional vision

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Abstract

Professionals working in the field of vision impairment face high expectations from the people they support. To meet this expectation, it is critical that professionals have a broad and in-depth knowledge of vision. This paper presents an overview of the two key entities that underpin an understanding of vision – visual function and functional vision. The contemporary professional literature is reviewed to present an examination of vision as a primary and essential sense, to develop an understanding of the dual components of vision and common approaches to vision assessment, and the key models that conceptualise vision in relation to the person and their environment.

Keywords

Visual function and functional vision.

Professionals working in the specialised field of vision impairment face high expectations from the people they support. In their role, professionals must implement strategies that mitigate for the impact of vision impairment for groups of people who have diverse requirements. This support must be individually tailored to suit the needs and aspirations of the person and their community, and to address the challenges posed by any existing eye and/or vision condition/s. Consequently, professionals must hold a sound knowledge of the complex nature of vision, understanding how vision is assessed and reported, and be ready to apply this knowledge to all areas of practice. Building this knowledge begins with an awareness of two key entities – visual function and functional vision, and the critical intersection between the two that supports an understanding of how a person sees.

To assist with building knowledge of the sense of vision, this paper presents a review of the professional literature that (i) defines and examines vision as a primary and essential sense; (ii) explores the existing dual approaches to vision assessment; (iii) and reviews key models that conceptualise vision in relation to the person and their environment. Given the broad scope of vision, the professional literature reviewed in this paper presents a greater focus on children than adults.

Defining vision

A commonly held notion is that the term vision refers to the basic functioning of the eyes. Although the eyes play a key role in the visual process, vision should be defined as a complex, continuous, and coordinated process involving critical structures within the visual system – the eyes, the visual pathway, the visual cortex, and other brain or cortical areas. Vision will only occur when all structures within the visual system are intact, continuously functioning and responding to the environment (Roberts et al., 2016).

Marr (2010) described vision as a process that involves both representation and processing of visual information by the eyes and brain, to know “what is present in the world and where it is” (p. 3). Zhaoping (2014) defined the visual process as one of input/output, or one that transforms three-dimensional objects from the visual world to two-dimensional images that are then available to the brain for the well-being of the person. This transformation is influenced by the person’s dynamic and complex environment where contrast, colour, brightness, and depth can vary (Jackson, 2007).

Colenbrander (2003) captured the complex nature of vision by proposing the existence of two interrelated components that he coined visual function and functional vision. Visual function represents the function of the anatomical organs, i.e., the eyes and visual system, and functional vision represents the ways a person functions in vision-dependent activities. Colenbrander (2003) drew on the International Classification of Functioning, Disability and Health Framework (ICF), a World Health Organization (WHO) framework, as a foundation for these definitions. The ICF recognises disability as a multi-dimensional experience, and incorporates components related to body functions and structures, activities and areas of participation, and environmental factors that may affect the person's participation (WHO, 2002). Colenbrander (2003) applied this notion to vision and contended that a person's vision could only be fully understood through knowledge of their visual function and functional vision, and the interrelationship that exists between the two. Colenbrander's (2003) dual component concept of vision is evident in the common approaches to the assessment of vision.

Assessment of vision

Dickinson (1998) identified several purposes for the assessment of vision including: (i) the capacity to compare a person's visual standard to an accepted standard, for example, a visual standard required for driving; (ii) to establish a baseline for comparison to monitor improvement and decline in visual performance; (iii) for the purpose of diagnosing ocular disorders; (iv) to quantify the person's subjective impression of their own performance in everyday circumstances; (v) for assessment of benefits; (vi) and to predict visual function for everyday tasks.

Dickinson (1998) concluded that no single vision test was available to satisfy visual measurement for all of these purposes, and acknowledged that the dual components of vision dictated the need for two assessment modes – visual function assessments and functional vision assessments. The choice of assessment mode is influenced by the reporting requirements and also by the needs of the person. For example, if the aim of vision assessment is to reach a diagnosis and to implement a disease management strategy, then a visual function assessment will be recommended. However, when the need exists to determine the personal impact of vision impairment, the recommendation will be a functional vision assessment (Dickinson, 1998).

Morse (2013) provided sage advice for professionals in recommending the point at which a functional vision assessment should follow a visual function assessment. Morse (2013) commented:

> Each component of vision is important because all vision-dependent tasks require a specific level of vision to perform them successfully and independently. While the seeming lack of objectivity in listening to and addressing patient narratives and their functional concerns may somehow seem like a step backward, a patient's concerns that evade detection on examination or do not comport with measured visual function should be sentinels for further evaluation and not be ignored (p. 667).

Markowitz (2016) further highlighted the situation where the results of vision assessment, usually defined by a person's visual acuity, rather than the outcome of functional assessment were applied when determining a person's eligibility for rehabilitation. Issues with this approach were identified, and Markowitz (2016) commented "it is obvious that in some situations current definitions do not reflect the functional disability experienced by an individual" (p. 62). In response, public system applying new definitions for vision impairment arose such as The Ontario Health Insurance Plan. The plan included assessment of cognition, residual visual function, eccentric preferred retinal loci, near functional vision, and reading skills; prescription of low vision devices; preparation of a vision rehabilitation plan; and supervised training.

Colenbrander (2010a) adopted a fit for purpose approach to vision assessment by highlighting the need to shift from visual function assessment to functional vision assessment, according to the person's needs. Figure 1 displays this shift, from determining threshold performance, i.e., visual function measured in a clinical environment, to determining sustainable and meaningful performance, i.e., functional vision measured in the person's everyday environment. Figure 1 also captures the consequence for the person being assessed, as the impact of vision impairment moves from the level of the eye, to influencing the person more broadly or functionally in their skills and abilities, to finally influencing the society the person lives in.

There is no doubt that purposeful approaches to vision assessment are essential. When an assessment aims at determining details about a person's functional vision but a clinically-based vision assessment is conducted, the results may be incomplete or incorrect conclusions derived about the person's functional capacity. Colenbrander (2005) illustrated this issue using the example of a standard vision assessment performed in a clinical environment using a typical vision chart (black letters that appeared on a white background viewed under stable illumination and contrast). Colenbrander (2005) concluded that

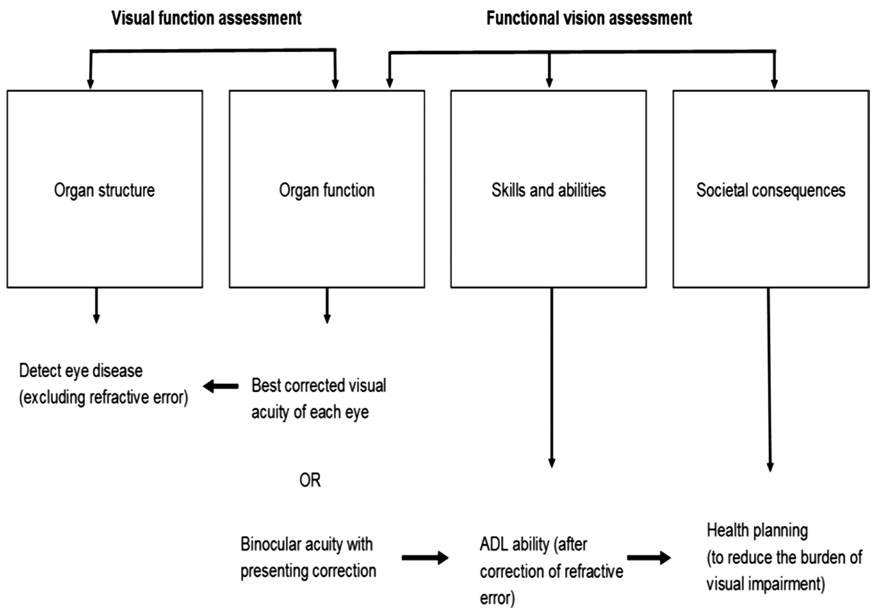

Figure 1: Fit for purpose approach to choice of visual or functional vision assessment. Adapted with permission from "Visual Impairment in Children due to Damage to the Brain" (p. 286), by G. N. Dutton and M. Bax, 2010, London: Mac Keith Press ISBN 9781898683865.

such an assessment failed to reveal information about the person's functional vision as it did not mimic the person's typical environment – one with frequent variations in size, lighting and contrast. Corn (1989) also concluded that clinical measurements provided a "ballpark in which to anticipate visual functioning" (p. 29) but do not predict a person's functional ability in completing a specific visual task with efficiency and comfort.

Several studies have highlighted the risk posed when visual function assessment outcomes (i.e., clinical measurements) have been inappropriately applied to determine the functional impact of vision impairment. Morse (2013) discussed a situation in which people with vision impairment may perform well functionally, despite the reduced visual function revealed by their clinical measurements. Conversely, Rand et al. (2015) described the potential risk for people with vision impairment when the functional deficits that occur with vision loss were not identified by vision assessment. They reinforced the need for vision assessment to be purposeful as these deficits were likely to affect the person's capacity for "[…] recovery of large-scale visual information" (p. 650), vital to the person's functioning within their environment.

The delineation between the two modes of vision assessment was explored by Colenbrander (2010a) who identified the discriminating features of each mode. These are summarized in Table 1.

Despite the need for delineation between assessment of visual function and assessment of functional vision, Berger and Porell (2008) described the interrelationship between the two as correlative and contextually dependent, i.e., this relationship could vary based on the person's environment. This interrelationship had been identified in an earlier quality of life (QoL) study by Massof and Fletcher (2001), where people with vision impairment demonstrated proportional visual ability with visual acuity scales. However, in reviewing this outcome Colenbrander (2005) cautioned that the relationship between visual ability and visual acuity scales found in this study only predicted an average QoL, and could not be applied to predict an individual's likely QoL.

Other approaches within the broad field of vision impairment also recognised the interrelationship within vision identified by Colenbrander (2003). For example, a Profile of Visual Function by Hyvärinen et al. (2012) was specifically developed for assessment of vision in children with brain damage-related vision loss. The profile included five key vision areas that represented both visual function and functional vision. Within each vision area a range of vision-related functions were rated depending whether they were normal or near normal, impaired but useful or profoundly impaired or non-functional. Table 2 outlines these key vision areas and provides examples of vision-related functions that were rated.

Table 1. Features of the visual function assessment and the functional vision assessment.

	Assessment of visual function	Assessment of functional vision
Examples	Visual acuity, visual field, contrast sensitivity, dark adaptation, colour vision	Use of vision to learn orientation and mobility, daily living skills, communication, sustained near activities, and to gain visual access to information
Measured	Separately for each eye	With both eyes open
Scale	Based on stimulus characteristics	Based on response characteristics
Tests	Single variable under controlled, usually static conditions	Multiple variables under real-life conditions
Criteria	Threshold performance	Sustainable performance
Involves	Visual parameters only	May also reflect non-visual factors

Adapted with permission from "Visual Impairment in Children due to Damage to the Brain" (p. 287), by Dutton and Bax (2010), London: Mac Keith Press ISBN 9781898683865.

Hyvarinen and Jacob (2011) reported that the Profile of Visual Functioning permitted a flexible approach to documenting function or impairment in a child's vision. Björkland (2014) commented that the profile was well suited to meeting the complex assessment process applied when determining vision in children with neurodisabilities. However, no further reporting on the Profile of Visual Functioning is currently available in the literature.

Table 2. Profile of visual functioning.

Key vision areas	Example of vision-related functions
Ocular motor	Fixation, saccades, scanning, accommodation, refraction
Sensory functions	Visual acuity near and distance, contrast sensitivity, colour vision, visual field
Early processing	Figure ground, background ground, stereovision, matching colours
Interior temporal networks	Face recognition, reading words, copying pictures
Parietal networks	Spatial awareness, body awareness, eye-hand coordination

Adapted from "What and How does this Child See?" (p. 153), by Hyvarinen and Jacob (2011), Finland: VISTEST. Reprinted with the author's permission.

Assessment of visual function

An exhaustive description of tools for vision assessment is outside the scope of this paper, so the key elements of assessment are provided. Assessment of visual function involves measurement of the integrity of a variety of parameters related to the visual system that may be altered by disease, anomaly and/or trauma, while applying certain protocols to this measurement approach (Dutton et al., 2010). These protocols usually include testing each eye in turn, with the goal of determining a threshold of performance (Colenbrander, 2010a), and ensuring that those vision tests used are equal to the person's capacity to participate (Dickinson, 1998). Assessment of visual function typically occurs in clinical environments that have been optimized to reveal the person's visual threshold, by minimising factors that could impact on visual function, for example, glare (Blais, 2011).

Assessment of visual function involves implementation of a series of tests, most commonly those for visual acuity and visual fields. Other tests such as the assessment of eye movements, pupils, colour vision, contrast sensitivity and stereopsis may be included in visual function assessment. Specialised ophthalmic testing may also be recommended as part of the assessment, according to the person's condition (Lueder, 2011).

Visual acuity is the most frequent clinical measurement of visual function conducted, and one that defines a precise metric, threshold or spatial limit in a person's ability to see (Levi, 2011; Morse, 2013). Traditionally visual acuity is measured as described by Matsuba and Soul (2010) using tests that assess the eye's capacity to "[…] identify black symbols on a white background at a standardised distance as the size of the symbols is varied" (p. 42). In doing so, the eye's ability to resolve the smallest high-contrast detail is assessed (Scheiman et al., 2007). However, visual acuity is not an all-encompassing measure of visual function, and is not representative of higher or cortically-related visual functioning (Colenbrander, 2010a).

Testing visual acuity can prove challenging due to the attributes of the person being assessed. For example, young children may struggle to participate in testing (Lueder, 2011), as may also people with intellectual disability (Hyvärinen et al., 2012). When a person is unable to participate in identification testing (i.e., reading letters from a vision chart), other approaches to visual acuity assessment may be adopted. The simplest approach is testing detection acuity where the ability to detect the presence of an object against a background is assessed (Blais, 2011). Resolution acuity may also be tested, by assessing the child's visual ability to discriminate a black and white striped grating from a homogeneous grey field with consistent luminance (Dickinson, 1998).

The visual field was defined early on by Traquair (as cited in Grzybowski, 2009) as "an island of vision or hill of vision surrounded by a sea of blindness." Matsuba and Soul (2010) further described the visual field as "the spatial array of visual sensations available for observation" (p. 42). Assessment of the visual field examines how much of the visual world a person can see while looking at or fixating on a defined target (Sheiman et al., 2007). The visual field is often termed peripheral vision representing an area where movement detection overrides detail recognition (Blais, 2011). Visual fields are not routinely assessed, but rather when pathology is suspected. Further, testing visual fields is challenging in children due to the level of cooperation required and the risk to reliability their level of cooperation may cause (Miranda et al., 2016).

Assessment of functional vision

Functional vision refers to the capacity of a person to function in vision-related tasks (Dutton et al., 2010). Corn (1989) summarised the aim of functional vision assessments as the determination of whether or not the person's visual abilities were "[…] sufficient for utilizing visual information in planning and/or execution of a task" (p. 28). Dutton and Hall Lueck (2015) qualified the difference between assessment of visual function and functional vision and commented:

> Functional vision is often described qualitatively, although quantitative measures are available for some tasks, such as reading. It is measured binocularly (both eyes viewing) to replicate "real world" performance, and examines supra- threshold (above threshold) performance so that a person's comfort level for an activity is identified and taken into account (p. 6).

The relationship between the abilities of a person with vision impairment and their functional vision is a recurring theme in the professional literature. Dutton et al. (2010) identified three principal elements of functional vision – for gaining access to information, for social interaction and for visual guidance of movement. Colenbrander (2003) described the link between functional vision and essential activities of daily living (ADLs), for example, reading, writing, face recognition and mobility. Roberts et al. (2016) highlighted the need for the identification of functional deficits related to these essential activities, and commented that non-identification potentially led to non-management that amplified morbidities such as risk of falls, depression and social isolation.

Kivelä (2010) reinforced the importance of understanding a person's functional vision by drawing a parallel between functional vision and general well-being. Kivelä (2010) described functional vision as the "[…] megatrend of the beginning decade of eye care" (p. 162), and encouraged a broadening of ophthalmic care beyond eye disease management, to include assessment of functional vision. Denver et al. (2016) echoed this opinion by proposing that functional vision be renamed visual ability. This change supported a shift in focus from measures of visual function denoting visual disability, to those that revealed functional impact but also "positive aspects or ability levels" (p. 1017).

Functional vision assessments are usually conducted in specialised low vision clinics to determine the person's visual abilities in a series of tasks. Clinical measurements such as visual acuity will often be repeated during the functional vision assessment, with the person's performance in tests such as visual acuity being supported by optical and non-optical devices (Presley and D'Andrea, 2008). Important information not immediately apparent in a clinical assessment may be revealed in a functional vision assessment including the impact of the person's age, health, motivation and psychological state (Dickinson, 1998). Colenbrander (2010b) identified essential visual skills and abilities that may be assessed including reading, orientation and mobility and ADLs. Further, assessment of the person's function in a variety of environments such as their home, school and community may also be undertaken, to evaluate their capacity to use their vision in their everyday situation (Guerette, 2014).

A variety of purposive functional vision assessment approaches appear in the literature, each one aiming to identify the person's needs. For example, Erin and Paul (1996) described an educational setting in which the functional vision assessment aimed at revealing certain instructional goals for rehabilitation. The need for repetitive assessment in environments such as the classroom, playground and other key school locations was emphasised, with an outcome that yielded clear recommendations for referral, adaptations, accommodations and services. Kammer et al. (2009) defined an optometry-led functional vision assessment that aimed at analysing the nature of the visual task, where the person's performance with and without low vision devices was assessed. In the case of children with Cortical Vision Impairment (CVI), Hall Lueck and Dutton (2015) described a multi-dimensional, tiered approach to the assessment of functional vision including observation of the child generally and then observation of the child in simple and complex environments performing a variety of activities. Roman-Lantzy (2018) developed the CVI Range which assessed the functional impact of CVI by identifying associated behaviours and the degree of impact of each behaviour on the child.

Conceptual models of vision

In the late 20th and early 21st centuries, literature addressing vision impairment conceptually served to broaden the understanding of the relationship between the two components of vision – visual function and functional vision. A shift toward considering the person and their functional needs, while retaining an understanding of the person's visual function (from clinical measurements such as visual acuity) became apparent. This was evident in Corn's Model of Visual Functioning (1983), and Colenbrander's Model of Health and Health Deficits (2003).

Corn's model of visual functioning

The Model of Visual Functioning was proposed by Dr Anne Corn (specialist educator) in the 1980s. This conceptual model presented a merging of clinical and educational perspectives, and further highlighted the multifaceted nature of vision (see Figure 2).

The model deconstructs vision into three major dimensions – the person's visual abilities; the clues within the person's environment that allow objects to be visible; and the person's individual stored and available traits such as past experiences and available functions. Corn (1983) maintained that relationships existed between individual components of the three dimensions and across the model, and that "[…] by intervening in one or more than one dimension, visual function may emerge" (p. 375). Corn (1983) encouraged professionals supporting children with vision impairment to consider and then apply the model "[…] to postulate how to elicit visual behaviours or to maximize visual function in individuals with low vision." Corn (1983) encouraged application of the model as "[…] a systematic approach to locating dimensions that compensate for minimal or reduced visual abilities, provide choices for the use of environmental cues, and contribute to an understanding of how individuals with low vision function visually" (p. 376). Corn (1983) also stated that when these dimensions were manipulated, the outcome could lead to improved visual efficiency.

An extended version of the Model of Visual Functioning was published in 1989, with the refinement of each dimension into the sub-dimensions. Corn (1989) commented that these sub-dimensions complemented and built on the original model's philosophical premises about the use of low vision. For example, the acuity dimension of visual abilities was expanded to include the sub-dimensions of near point, midpoint and distance, to permit consideration of a variety of viewing distances (Corn, 1989). Within the colour dimension of environmental cues, sub-dimensions of brightness, hue and saturation were added to recognise those specific characteristics of colour appreciation that can be affected by vision impairment. Within the cognition dimension of stored and available individuality, the sub-dimension of intelligence, problem solving, communication, concept development, memory and experience were added to expand the understanding of the person.

Corn's Model of Visual Functioning has been frequently cited in the literature since its release. Barraga (1990) referred to the model as a seminal work that was critically important to the field of education of students with vision impairment. Holbrook (2015) described the initial paper that presented the model as a classic publication, and the model as one that had stood the test of time by transcending educational practice. The model has been used in various contexts including its use as the basis of

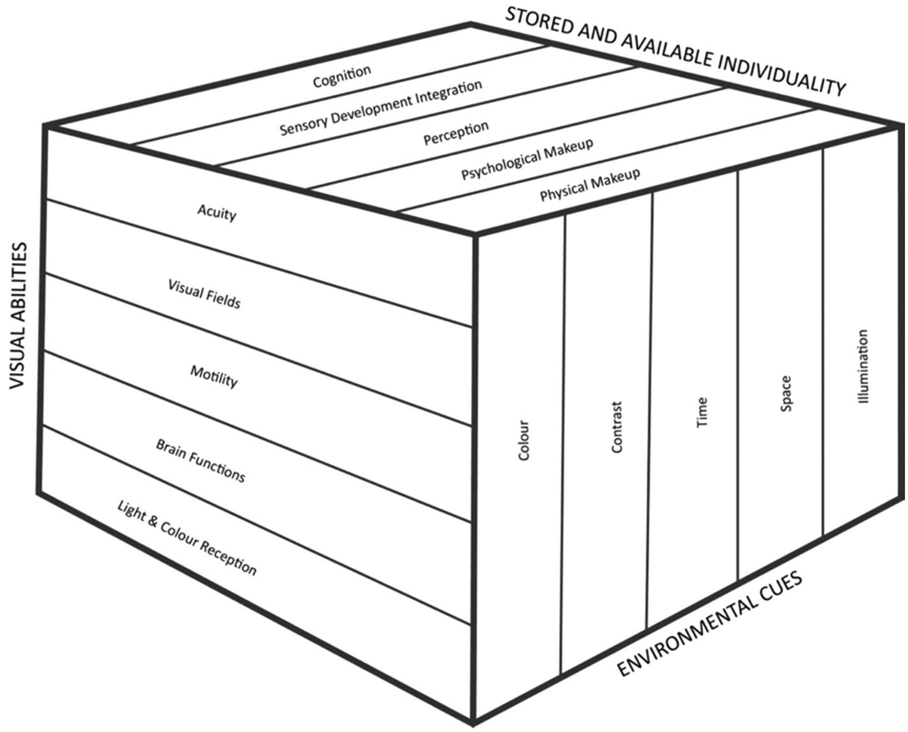

Figure 2: Model of Visual Functioning. From “Visual Function: A Theoretical Model for Individuals with low Vision,” by A. L. Corn (1983), *Journal of Visual Impairment and Blindnesss* 77, p. 374. Copyright © 1983 by American Foundation for the Blind. All rights reserved.

frameworks (Corn and Koenig,1996; Cox and Dykes, 2001); to identify personal attributes and needs (LaGrow et al., 1998; Meyer and Green, 2007); and to identify environmental factors that may impact on a person with vision impairment (Heller et al., 1998).

Colenbrander’s model of health and health deficits

The ongoing work of Dr August Colenbrander (ophthalmologist) introduced another important model related to vision. Whereas Corn (1983, 1989) closely examined the components related to the person and their environment, to draw a conclusion about visual efficiencies and functioning, Colenbrander placed the person being assessed in a broader context, one that included service provision. In 2003, Colenbrander presented the Model of Health and Health Deficits in the context of vision impairment, seen in Figure 3. This model demonstrated a continuum where a person increasingly relied on services as the impact of their vision impairment escalated to affect their functional ability. The Model of Health and Health Deficits addressed the shift from considering ‘the organ’ or the pathology affecting the eye, to recognising the functional change through which the person’s skills and abilities were affected. This functional change was linked to extended consequences in the social and economic domains by Colenbrander (2003).

In some respects, Colenbrander’s model paralleled Corn’s (1983) Model of Visual Functioning by presenting vision as a complex entity. Both models extended thinking beyond reliance on visual function as the key representation of a person’s visual capacity. Colenbrander (2003) commented “knowing how the eye functions does not tell us how the person functions” (p. 164), meaning clinical measurements of visual function indicate the function of the organ or eye, rather than the visual capacity of the person to function in their chosen environment.

The Model of Health and Health Deficits has been applied by authors contextually to vision impairment (Berger and Porell, 2008; Crews et al., 2012); and as a framework for the outcomes of certain interventions (Neves et al., 2005).

In 2010, Colenbrander published a revision of the Model of Health and Health Deficits that extended the model to include the assessment outcome of various interventions (seen in Figure 4). In this updated version, Colenbrander (2010b) sought to show the link between the specific components of the person with vision impairment, (e.g., the eye or the person), and

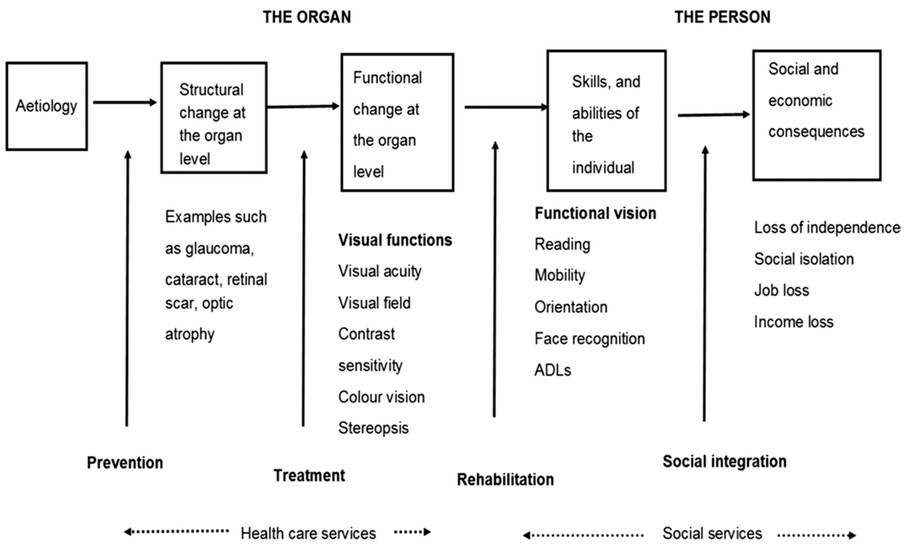

Figure 3: Model of Health and Health Deficits. From “Aspects of vision loss – visual functions and functional vision,” by A. Colenbrander (2003), *Visual Impairment Research*, 5, p. 116. Reprinted with permission http://www.tandfonline.com.

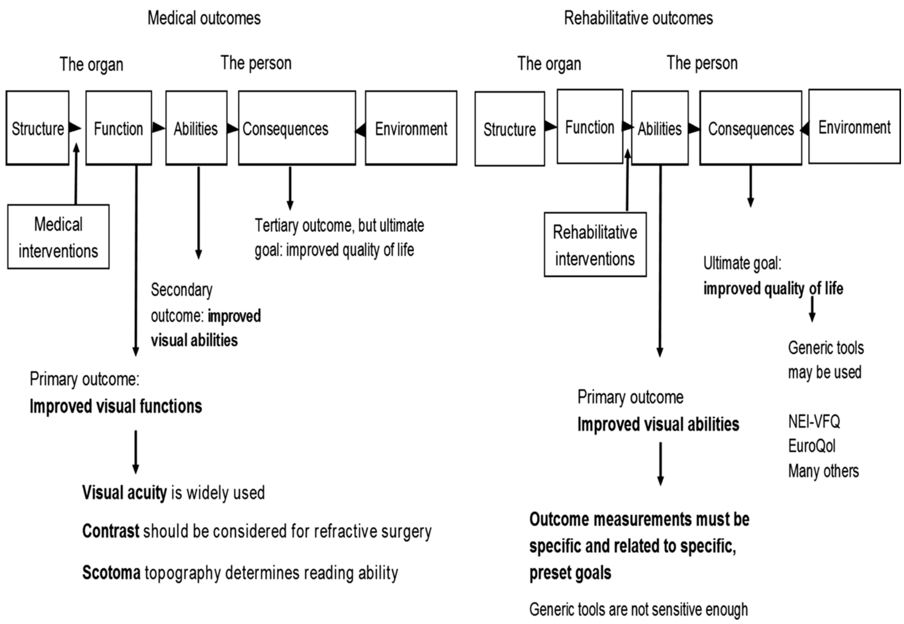

Figure 4: Revised Model of Health and Health Deficits. From “Assessment of functional vision and its rehabilitation,” by A. Colenbrander (2010), *Acta Ophthalmologica*, 88, p. 165. Reprinted with permission http://www.tandfonline.com.

outcomes (primary, secondary or tertiary) according to the intervention. Crews et al. (2012) commented that the revised model demonstrated “the specificity and utility of vision measures in rehabilitation” (p. 41). Importantly, Colenbrander (2010b) added QoL in this version of the model as the ultimate consequence of medical care and rehabilitation.

Conclusion

The field of vision impairment holds high expectations of professionals, envisaging that they will work efficiently in a variety of environments, and across a diverse population of people, family and community. To support a foundational understanding of the complex nature of vision this paper provides professionals with an examination of the dual components of vision– visual function and functional vision – and the ways that each component is typically assessed. The interrelationship between these components has been explored, as have the challenges associated with vision assessment. Key models that conceptualise vision in relation to the person and their environment have also been examined. It is with knowledge of the concepts addressed in this paper that professionals are well-positioned to fulfil their critical and demanding role working when working with people with vision impairment.

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