Development of the Visual Field

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Introduction

The visual field is defined as the area that can be seen when the eye is directed forward and steadily fixating, including that which is seen with peripheral vision. The visual field is almost always tested one eye at the time, and there are several methods and more or less advanced equipments for visual field testing (also called perimetry). This chapter describes visual field testing in children and factors influencing the visual field development and the test results.

Methods for testing the visual field in children

A simple, although quite informative way of testing the extent of the visual field is ad modum Donders, when you use your own hands as stimuli, and your own visual field as reference. This method is used in adults to detect large constrictions and when no equipment is available. For quantitative testing of the sensitivity within the visual field, computer assisted techniques are preferred. Since most of the diseases affecting the visual system first affects in the central part of the visual field (although not necessarily affecting the area for reading ability; the fovea), most computerized perimeters test the central 30° area. In children, however, it is sometimes interesting also to test the extent of the visual field, and then different manual methods, possible to adapt to the children’s age and ability to co-operate, have to be used.

In small children, testing the visual field is a challenging task. A number of different methods have been developed but only a few of them have been adequately evaluated. In very young children a variant of “preferential -looking” is used, in which the examiner observes if the
infant shifts gaze when a stimulus is presented. In toddlers the so called ball-on-a-stick can be used. Pre-school children are able to co-operate in a manual Goldmann examination and school children can perform computerized perimetry (Fig 1).

![Figure 1. Different techniques for visual field testing. Goldmann perimetry (Courtesy of Luisa Mayer) (Left), Computerized perimetry: Rarebit perimetry (Right)](image)

**The Normal Visual Field in Children**

Measuring the visual field in young children; infants and toddlers, is complicated. Yet, several studies have provided knowledge about the extent of and sensitivity in the visual field in the growing child, even if different reports give somewhat varying results. The extent of the visual field in small children is also depending of the method used; kinetic or static, the size of the stimulus and, in children at 1-2 years of age, also on the presentation of competing stimulus in the fixation area.

The effective visual field has been shown to expand between 2 and 4 months of age and the ability to respond to peripheral objects more distant than the fixation object develops after 3 months. Visual field extent corresponding to adult levels has been reported to be present at 17 and 30 months of age, measured with kinetic and static perimetry, respectively (Dobson et al 1998), see figure 2.
**Figure 2.** Visual field extent in different ages measured with 6° stimulus (Goldmann III – IV). Thin continuous blue line = newborn, dashed blue line = 3.5 months, thick continuous blue line = 7 months, red dash/dot line = 4 years, blue dash/dot line = adult (adapted from Dobson et al 1998).

Regarding the standard tests, routinely used in adults, it is well known that the child has to reach an age of 5-7 years before reliable visual field results can be expected. Using the most common computerized methods the extent and sensitivity values, equal to those from adults, can be obtained at the age of 10-12 (Martin 2005, Martin & Lundvall 2007; 2009).

**Attention**

One main reason for the different results in children and adults, especially regarding static and moving stimuli, may relate to differences in peripheral summation areas or to differences in attention between infants and adults. The visual field in pre-school children is affected by non visual factors, such as vigilance and cognitive processes (Tschopp et al 1998). From the age of 5 to 7, the child is able maintain steady fixation on a target and to respond to a stimulus presented in the periphery by pressing a button. But in younger children and infants, the examiner has to rely on the fixation eye movements of the child. However, infants between
approximately 1 and 4 months of age were reported to have difficulty with disengagement, i.e. looking away from a stimulus, once their attention has been engaged (Hunnius 2007).

The eccentricity to which infants move their gaze to locate a target has been found to increase rapidly during the first 4 months of age (Harris & MacFarlane, 1974; Lewis & Maurer, 1992). Despite this fast early development, several studies report that an adult-like performance is not attained before the end of infancy or even the school-age years. Other authors have reported that from the age of approximately 6 months, infants’ performance when shifting gaze between two stimuli is comparable to that of adults (Atkinson et al, 1992).

Normal visual field development

As has been stated above, there are numerous studies using manual perimetry for examining the visual field in children and for evaluation of the extent of the visual field. We have been interested in evaluating new computerized perimetric methods in children for evaluation the sensitivity of the central visual field, both in healthy children and pediatric patients. Two methods have been used, both developed in Sweden; the high-pass resolution perimeter (HRP (Frisén 1993; Martin et al 2008a) and Rarebit perimetry (Frisén 2002; Martin 2005). Especially the latter was found to be suitable for children of at least 6 year of age. The method is sensitive to low-degree damage, very patient-friendly, requires short examination time and is preferred by the children, when compared to other techniques (Martin et al 2004).

Figure 3 shows a summary of five of our studies of healthy children of different ages, evaluating the normal values established with Rarebit perimetry (Martin et al 2004; Martin 2005; Martin & Lundvall 2007; Martin et al et al 2008b; Hellgren et al 2009).

Abnormal visual field development

There are several factors that can disturb the normal development of the visual field. In several studies we have described the effect of intrauterine incidents, intrauterine growth restriction, premature birth, treatments for side effects of premature birth (retinopathy of prematurity) and other hinders for the normal visual development such as ametropia, strabismus and congenital cataract.
Figure 3. Results from computerized perimetry (Rarebit perimetry), expressed as a percentage of stimuli seen (hit rate) from age 7 to 20 (healthy subjects). Note the low increase in hit rate from age 7 to 12 and the somewhat larger variability in examination results in younger children (Martin & Lundvall, submitted).

Prematurity and co-morbidity

Prematurity influences the visual system in several ways. In a follow-up study of 11-year old children, born prematurely, we could confirm findings in previous studies, i.e. that children treated for retinopathy of prematurity have somewhat constricted visual fields compared to age-matched controls. But we could also show that prematurity per se reduced the sensitivity in the central visual field (outside the fovea), presumably reflecting a reduced density of retino-cortical neural channels (Larsson et al 2004). This was true also for children born small for gestational age due to intrauterine growth restriction (Martin et al 2004).

Approximately one third of the children born prematurely and/or with very low birth weight have cerebral sequelae, such as white brain matter damage (Olsén et al. 1997). Studies regarding visual outcome, especially the visual field are sparse, due to the wide-spread misunderstanding that quantitative perimetry is not possible in these children. However, using a combination of the manual kinetic Goldmann perimetry for examination of the extent of the visual field, and one of two computerized techniques for examining the central visual field, we were able to carefully examine a number of prematurely born teenagers and young adults.
with visual dysfunction due to white matter damage of immaturity of pre- or perinatal origin. They all had subnormal visual field function, although the depth and extension of the defects differed between subjects. Typically, the inferior field function was more impaired than the superior. We could also show that, as in adults, the static computerized techniques revealed a slightly higher frequency of abnormality (Jacobson et al. 2006) compared to Goldmann perimetry.

In a separate study of adolescents with very low birth weight (<1500 g) we found that the subjects are at a disadvantage regarding visual outcome compared to subjects with normal birth weight (Hellgren et al 2007). Almost one fifth of all VLBW children, and 40% of those with white matter damage, had subnormal visual fields (Hellgren et al. 2009).

**Congenital cataract**

It is well known that dense cataract, even when surgically treated early in infancy, causes persistent impairment of visual acuity. Recently we have shown that not only the extent of the visual field, but also the sensitivity in the 30-degree visual field is affected, although less pronounced than visual acuity (Martin et al. 2008a). This finding has to be taken into account when evaluating visual field results in for example in the diagnosis of glaucoma, a frequent complication after cataract surgery in early infancy.

**Glaucoma**

Computerized visual field examinations are gold standard in the diagnosis and follow-up of glaucoma. Nevertheless, not many studies are published using computerized perimetry in pediatric glaucoma. We have found that the Rarebit perimetry is well suited for glaucoma management in children (Martin & Lundvall 2007). Recently we could show that the visual fields remained essentially unchanged during 5 years of follow-up in children and adolescents, carefully treated for glaucoma (Martin & Lundvall 2009).

**Conclusions**

Visual fields develop rapidly during early infancy as shown in studies with tests appropriate for the age of the child. However, conventional perimetric techniques are less suitable for children below the age of 7 to 12 years. Recent developments in perimetric methods may improve the ability to detect visual field abnormalities in even younger children.
References


Martin L & Lundvall A (2010): Rarebit Visual Field Follow-Up in Pediatric Glaucoma (submitted for publication)
