• Investigation •

Age norms for grating acuity and contrast sensitivity measured by Lea tests in the first three years of life

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Abstract

● AIM: To determine age norms in the first three years of life for grating visual acuity and contrast sensitivity obtained with Lea grating test and Hiding Heidi low contrast face test.

● METHODS: Lea grating test was used to estimate binocular grating acuity and Hiding Heidi low contrast face test was used to estimate contrast sensitivity in 600 healthy infants and children. Age ranged from 3 to 36mo subdivided into 12 groups subjected for full ophthalmologic and pediatric examinations.

● RESULTS: The grating acuity developed along the first three years of life. It ranged from 1.88±0.32 c/d at 3mo to 30.95±0.77 c/d at 36mo. The most rapid development was during the first 12mo and the slowest development was from 30 to 36mo. The contrast sensitivity showed rapid development in the first two years of life. Its mean value ranged from 4.23±1.17 at 3mo to 78.26±8.21 at 24mo. It was constant at the highest score (80) thereafter.

● CONCLUSION: Age norms for grating acuity along with contrast sensitivity offer a more comprehensive measure of spatial vision and should be incorporated in clinical practice for better visual assessment in preverbal and nonverbal children.

● KEYWORDS: grating acuity; contrast sensitivity; age norms; Lea tests, preverbal children

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INTRODUCTION

The visual system undergoes tremendous development during the postnatal period and in the first few years of life. During this critical period, visual circuits mature and are refined by sensory experience allowing development of normal vision[1]. In human and primates, higher form vision matures substantially later than spatial acuity and contrast sensitivity[2]. Recognition acuity, which uses standard line tests, cannot be used in examining infants and preverbal children. Instead of recognition visual acuity (VA), resolution (grating) acuity is measured.

Behavioral (preferential looking; PL) techniques as well as electrophysiological technique [sweep visual evoked potential (VEP)] are the methods used for measuring grating acuity and contrast sensitivity in pre and non-verbal children. These techniques had been used to track development of infants' acuity, contrast sensitivity and binocularity, and for clinical evaluation of developing visual function[3].

PL technique was first done in the laboratory through complex psychophysical procedures. Then acuity cards were developed in an attempt to make PL more applicable to clinical setting. These cards do not require literacy and allow testing well within the child's limited attention span. Correct responses can be immediately verified and the test can be carried out within a short period of time. Contrast sensitivity is tested using sinusoidal grid patterns of varying contrast and spatial frequency. In routine practice, however, this is usually achieved more easily with acuity cards on which contrast is reduced in several stages[4]. In addition, development of face processing abilities appears to start very early in infancy. For example, within the first few days of life, newborn infants display preferences for faces versus objects. Then a variety of face processing abilities continue to develop well into childhood, including face recognition[5]. Therefore, low contrast face pictures can be used together with low contrast VA cards to assess perception of low contrast large forms.

Defining of age norm for grating acuity as well as contrast sensitivity is very important for a comprehensive assessment of visual function. These measures help in identifying children in high-risk such as amblyopia[6], ocular pathology[7] and cerebral visual impairment[8]. They also provide a role in monitoring of disease and treatment[9], and determine the criteria for visual rehabilitation[10].

The aim of the present study is to determine grating VA and contrast sensitivity obtained with Lea grating and Hiding Heidi low contrast face tests in the first 36mo of life and to establish the age norms for these measures.

SUBJECTS AND METHODS

The sample consisted of six hundred normal healthy infants and children; they ranged from 3 to 36mo of age were born within 3wk of 40wk gestation and were assigned to age groups on the basis of post-term age. The children were selected from ministry of health care centers. All participant children were subjected to full pediatric and neurologic examinations to exclude any possible disorder. Complete ophthalmologic examination, including external eye inspection, assessing ocular motility, cycloplegic retinoscopy, indirect ophthalmoscopy, and corneal reflexes was done to exclude any apparent ocular deviation, errors of refraction, fundus alterations and ocular diseases. Children with any known systemic or ocular abnormality or who were at risk for eye disorders by family history were excluded from the normal sample.

Apparatus and Procedure

Grating acuity Grating acuity was assessed binocularly with Lea gratings test (#253300-a number of paddles to present grating of decreasing width). The grating is defined as cycles per centimeter (cpcm) (GOOD-LITE). The grating paddle stimulus used were: 1, 2, 4 and 8 cpcm. The measurement was based on observing the child's eye movements. When the grating paddles were presented to the child, the infant was shown the grating simultaneously with the gray stimulus. We started with the coarsest grating, and then showed every other grating in succession. The VA threshold was determined by the spatial frequency of the last card that received two positive responses. If the infant or child lost interest, a face figure or colorful toys would motivate the infant to respond again. Children from 3 to 6mo of age were tested at the distance of 57 cm, this is a convenient test distance because number of cpcm corresponds to grating acuity as cpd. Children from 7 to 36mo of age were tested at distance of multiples of 57 cm; 85, 114, 172 and 229 cm. When a distance longer than 57 cm was used, the cpd results were calculated using this formula:

$$\frac{\text{Distance used}}{57.2\text{ cm}} \times \text{cpcm} = \text{cpd}$$

Contrast sensitivity Contrast sensitivity was assessed binocularly with Hiding Heidi low contrast face test (#253500). The test is a number of cards with face picture that presented in the order of decreasing contrast 100%, 25%, 10%, 5%, 2.5% and 1.25%. The contrast sensitivity value for these cards equals 1, 4, 10, 20, 40, 80 respectively.

The picture cards were presented by moving the picture and white card with the same speed horizontally. The measurement was based on observation of the infant's responses to the faces either by eye movements, head turning, eye widening, eye brow arching, smiling, babbling to or reaching for an object. In older children, the child was asked to point to the Heidi face when she became visible. The testing distance used was the same as for VA testing. The contrast sensitivity threshold was determined by the contrast value of the last card that received positive response.

Statistical Analysis A computerized database for survey data was developed. Data entry and statistical analysis was carried out using Statistical Package for Social Science (SPSS) version 18. The study group was divided into twelve age groups of three months each starting with the age group three months and ending with the age group thirty six months. Both descriptive and analytical statistics were performed. The data analysis began with calculation of frequencies and percentages of the variables of interest. Statistical significance was assessed at 5% level. The grating acuity and contrast sensitivity variables were tested for normality. Mean, standard deviation, upper and lower confidence limits were calculated for both variables in relation to the twelve age groups and presented as tables and graphs using Microsoft Excel program version 7.

Table 1 Mean grating acuities and their respective standard deviations for twelve age groups in 600 healthy full-term children

Age groups (mo)	*n*	Mean	SD	Lower limit	Upper limit	Decimal VA
3	26	1.88	0.32	1.0	2.0	0.06
-6	75	4.80	1.53	2.0	8.0	0.16
-9	54	9.13	2.49	8.44	11.8	0.30
-12	107	12.86	2.29	8.0	16.0	0.42
-15	58	15.16	0.51	14.4	16.0	0.50
-18	65	18.86	2.25	16.0	24.0	0.62
-21	35	22.53	1.61	20.8	24.0	0.75
-24	69	23.72	1.88	20.8	30.4	0.79
-27	26	26.58	3.38	20.8	30.4	0.88
-30	33	28.06	3.86	20.8	32.0	0.93
-33	9	29.51	3.21	24.0	32.0	0.98
-36	43	30.95	0.77	30.4	32.0	1.03

SD: Standard deviation; VA: Visual acuity. Lower and upper normal limits are also shown. Along with these results, the decimal VA equivalent for grating acuities were included.

RESULTS

Grating Acuity Results Mean grating acuity and their respective standard deviations of the data obtained under binocular viewing conditions for each age group from 3-36mo of age are shown in Table 1 and Figure 1.

Mean grating acuity value at three months was 1.88±0.32 c/d ranged from 1.0 to 2.0 c/d , the grating acuity developed rapidly in the first year. The mean grating value was 4.80±1.53 c/d at the 6mo and reached 12.86±2.29 c/d at 12mo. In the second

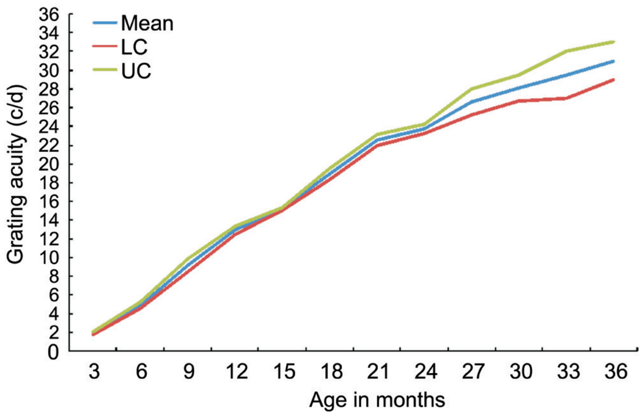

Figure 1 Grating acuity development in the first 36mo of age LC: Lower confidence limit; UC: Upper confidence limit.

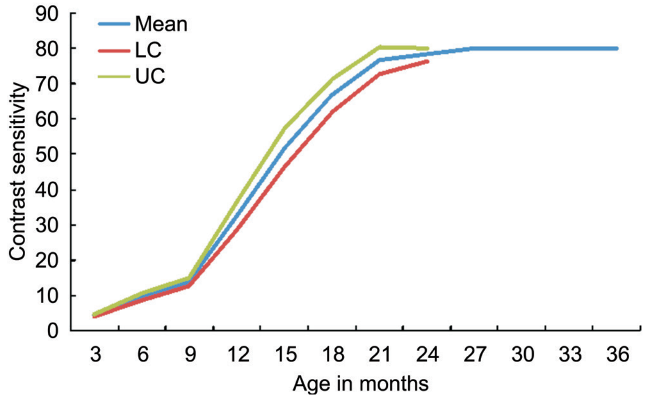

Figure 2 Contrast sensitivity development in the first 36mo of age LC: Lower confidence limit; UC: Upper confidence limit.

year, the grating acuity developed gradually, its mean value at 24mo was 23.72±1.88 c/d. Then it develops at a slower rate in the third year. At 36mo the grating mean value was 30.95±0.77 c/d.

Contrast Sensitivity Results Mean contrast sensitivity and their respective standard deviations of the data obtained under binocular viewing conditions for each age group from 3-36mo of age are shown in Table 2. Mean contrast sensitivity values were 4.23±1.17 at 3mo and 78.26±8.21 at 24mo. During the third year the contrast sensitivity was 80 and showed no change until 36mo. The contrast sensitivity developed gradually in the first 9mo. Then, the contrast sensitivity scores increased steeply from 9 to 18mo. After that it showed no change (Figure 2).

Table 2 Mean contrast sensitivity and their respective standard deviations for twelve age groups in 600 healthy full-term children

Age groups (mo)	*n*	Mean	SD	Lower limit	Upper limit
3	26	4.23	1.17	4	10
-6	75	9.60	5.31	4	20
-9	54	13.70	4.87	10	20
-12	107	32.43	21.18	10	80
-15	58	51.90	21.47	10	80
-18	65	66.77	19.45	20	80
-21	35	76.57	11.36	40	80
-24	69	78.26	8.21	40	80
-27	26	80.00	0.00	80	80
-30	33	80.00	0.00	80	80
-33	9	80.00	0.00	80	80
-36	43	80.00	0.00	80	80

SD: Standard deviation. Lower and upper normal limits are also shown.

DISCUSSION

In the present study, we keen to establish normative data. This was achieved by getting a sufficient large sample that can be representative of the population. Every tested child was submitted to ophthalmologic, pediatric and neurologic examination to rule out the possibility of including pathologic cases in the normal sample.

The presented grating acuity and contrast sensitivity results measured by Lea cards confirm and extend previous findings regarding the normal development of spatial vision. In this study the grating acuity measured lea cards developed rapidly in the first year then gradually in the second year. In the third years, it reached to a slowest rate from 30 to 36mo as shown in Figure 1. This is in agreement with the study of Shi *et al*[11], they used the closed-circuit operant preferential looking system.

The presenting PL grating acuity values are very close to that previously measured by sweep-VEP at age of 12, 24 and 36mo[12]. Sweep VEP estimates exceed our grating acuity values only in the first 6mo of life but they become nearly similar after that. These finding are considered consistent in spite of stimulus differences between electrophysiological and behavioral acuity assessment (static stimulus versus changing stimulus involving motion for VEP).

On the other hand, previous studies used Teller acuity cards for measuring grating VA although all agree that VA increases progressively with age, however their results were different in different age period. Qiu *et al*[13] reported that VA of the infants aged form 5 to 14mo increased slowly and the increase started from 15mo. At 24mo VA value was near to adult level. While Salomão and Ventura[14] stated that a steep increase in VA is observed from birth to approximately 6mo, followed by shallow growth thereafter. In the presenting results, our estimated grating acuities exceed those in Qiu *et al*[13], study in the first year of life and exceed the grating values in the Salomão and Ventura study in the second year of life. These differences are reasoned that Lea grating paddles are tested at increasing distances according to age group, and the larger field of cards may be more familial to the child and might contribute to the children's cooperation in the test situation.

The grating acuity progress along the first years of life is explained by visual system development. Regarding retinal maturity, cone photoreceptors distribution becomes more dense and aligned[15]. During this period more synaptic connections are established in the visual cortex[16].

The contrast sensitivity results also exhibited rapid development in the first two years of life. Contrast sensitivity remained stable at the highest value thereafter. The sharpest rise in contrast sensitivity mean values were observed from the age of 9 to18mo.

These contrast sensitivity findings are in consistent with numbers of studies on face processing in infants and children illustrated that infants have a low-spatial frequency bias for face processing. Faces stimuli are biologically significant, and are processed quite efficiently[5,17]. Our results suggest that the Hiding Heidi test could assess perception of low contrast large forms for infants with normal vision from 3 to 24mo. The test sensitivity is limited for evaluating contrast sensitivity above the first two years of life.

The Hiding Heidi test was used by Leat and Wegmann[18] to measured contrast sensitivity in normal children from 1 to 8y. They found that most children of all ages correctly responded to the lowest contrast (highest contrast sensitivity). In contrast, our study revealed that the contrast sensitivity is positively related to increasing age giving the age norm in the first 24mo of live (Figure 2). Possible reasons could account for the differences in results between our study and that of Leat and Wegmann[18]. First, it could be that their study was conducted on relatively small number of children. Second, their study didn't include the age group below one year.

The mechanisms underlying face processing in infants is based on low-spatial frequencies hypothesis: there are two systems for face processing, one subcortical (through the superior colliculus, pulvinar, and amygdala), and the other cortical (involving the fusiform face area). The subcortical system is more responsive to low spatial frequencies, while the cortical system is more responsive to high spatial frequencies, and infants rely more on subcortical face processing mechanisms, partially because the cortical system takes longer to mature[19-21].

In conclusion, the grating acuity norms measured by Lea acuity cards will be useful in clinical practice and for diagnosis of visual status in infants and preverbal children.

The grating acuity normal values measured by Lea acuity cards were the nearest to that measured by sweep VEP. Contrast sensitivity age norms using the Hiding Heidi contrast sensitivity test has good potential as an additional tool for assessing spatial vision in infants up to 24mo. Grating contrast sensitivity test including higher spatial frequencies may be recommended for evaluating contrast sensitivity development in older preverbal children.

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Conflicts of Interest: **Elgohary AA,** None; **Abuelela MH**, None; **Eldin AA**, None.

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