

THE OCULAR MOTOR DEVELOPMENT OF INFANTS

LINDA MCKENZIE, Dip AppSci(Orth), DOBA

Division of Orthoptics, Lincoln School of Health Sciences, La Trobe University, 625 Swanston Street, Carlton, Vic 3053

Abstract

The aim of this longitudinal study was to record the development of ocular motor responses of infants observed in the routine clinical environment during the first year of life. The fixation, smooth pursuit and saccadic responses to different stimuli at various age groups are outlined. The responses to the fusion reflex test using a 10 and 20 dioptre prism are also described.

Key words: *infant, ocular motor development, fixation, smooth pursuit, saccades, convergence, binocular response.*

INTRODUCTION

There have been many laboratory studies of infants' ocular motor behaviour such as those by Kremenitzer et al,¹ Hainline,² and Barten et al³ studying the characteristics of fixation, smooth pursuit and saccades. One study using clinically based assessment techniques by LaRoche and Anderson⁴ of 40 normal neonates demonstrated the preferential response of infants for the human face, reporting that 83% of the infants looked at and followed an examiner's face, with none responding to a penlight. They also reported that 73% of the neonates showed some response to OKN strips. This study by LaRoche and Anderson⁴ assessed the infants only in the first days of life.

Two previous studies on the development of binocular function have shown conflicting results. Coakes et al,⁵ using an 8 dioptre and a 15 dioptre prism, reported that a response was observed to a smaller prism at a younger age than to a larger prism. This pattern of development is contradictory to that reported by Aslin^{6,7} who suggests the hypothesis that infants require a larger retinal disparity as a stimulus to motor fusion than do adults.

The aim of this longitudinal study was to record the development of ocular motor responses of infants observed in the routine clinical environment during the first year of life.

METHOD

Systematic sampling of infants born at Monash Medical Centre, Clayton Campus was carried out. Parental consent was gained for the one hundred and one infants tested. To be included in the sample infants were to be full-term with uncomplicated delivery and normal neonatal assessment. Table 1 gives a description of the sample showing the range of normal infants.

The infants were assessed during the first week, then at 1, 3, 6 and 12 months. Fixation was observed using the examiner's face, a penlight, a visual object and a sound-making visual toy to gain the infant's attention. The examiner's face was used as a fixation object only until a reliable response was obtained from other stimuli, so was not recorded beyond 1 month of age.

The following aspects of ocular movement were assessed both horizontally and vertically;

- smooth pursuit was assessed using the same

Address for correspondence: Linda McKenzie, Division of Orthoptics, Lincoln School of Health Sciences, La Trobe University, 625 Swanston Street, Carlton, Victoria 3053.

TABLE 1
Description of sample (N=101)

Variable	Mean	Standard Deviation	Range
Gestation (weeks)	39.7	1.05	37-42
Birth weight (grams)	3327	429	2212-4670
Apgar score: 1 min	8.4	1.02	4-10
Apgar score: 5 mins	9.6	0.53	8-10
Maternal Age (years)	27.9	5.46	17-40

- stimuli as those used to gain ocular fixation.
- saccades were assessed using the examiner's face, a penlight, a visual toy and an auditory stimulus to gain a refixation response.
 - optokinetic nystagmus using an OKN drum.
 - doll's head vestibular responses were assessed only at the neonatal and 1 month examination.
 - convergence using a visual object.

The binocular response was assessed using a 10 and 20 dioptre base-out prism to observe the fusion reflex. A visual object with a penlight was used as the fixation target.

Visual acuity was assessed using Teller Acuity Cards. Each of the infants had a retinoscopy and fundus and media examination performed under cycloplegia with Cyclopentolate 1%.

RESULTS

The number of infants tested in each age group is recorded in Table 2. Sixty nine infants were able to be fully assessed at the first visit, four infants fell asleep during assessment and the remaining twenty eight were asleep at the time of testing and unable to be wakened. Of the ninety two infants returning for the 1 month assessment, four were unable to be wakened. At all other testings, all infants were awake.

The Teller Acuity results fell within the normal range as recommended by other authors.^{8,9} Retinoscopy results showed a refraction of mean

TABLE 2
Number of Infants Tested

Mean Age	Standard Deviation	Range	Number Tested
4 days	1.36	2-7	73
30.9 days	3.02	26-46	92
13.7 wks	1.28	11-18	85
26.3 wks	1.95	22-34	83
52.4 wks	2.04	47-60	74

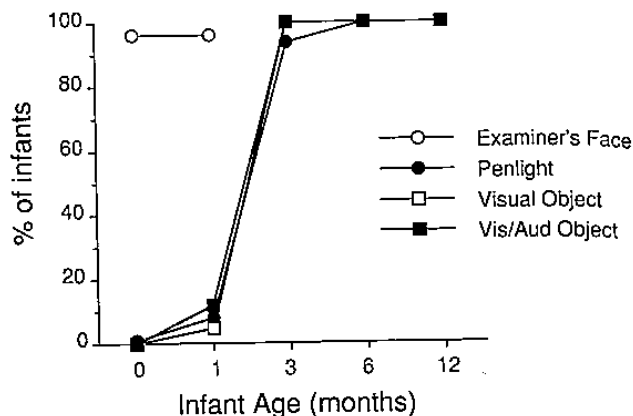


Figure 1: Fixation response.

spherical equivalent of RE +3.00 dioptres (SD ± 1.01) and LE +3.00 dioptres (SD ± 1.02), with a mean cylindrical error of RE 0.27 dioptres (SD ± 0.48) and LE 0.24 (SD ± 0.43), with no significant difference between right and left eyes using a paired t-test. The range of refractive error extended from 0 to +6 dioptres of spherical equivalent and 0 to 2 dioptres of cylindrical error.

Figure 1 demonstrates the fixation responses to the different stimuli. It can be seen that the neonates responded only to the examiner's face, 96% giving a fixation response. Only one infant was observed to fixate the penlight. At 1 month similar results were obtained, but with more infants fixating the visual/auditory object (12%) and the penlight (8%). At 3 months there was a 100% response to all stimuli except the penlight which gained a fixation response in 94% of the infants.

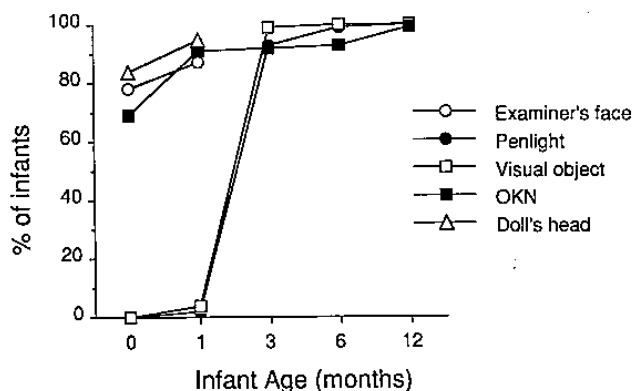


Figure 2: Horizontal pursuit/following response.

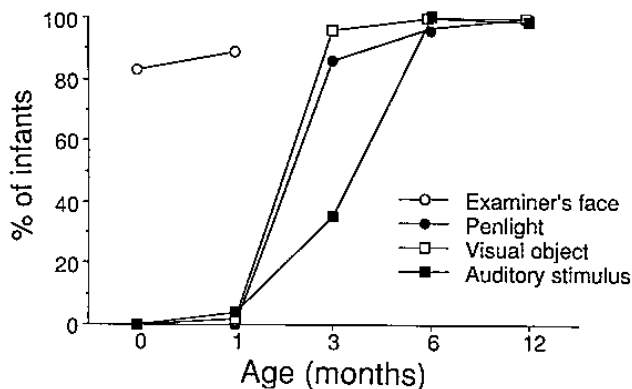


Figure 3: Horizontal refixation/saccadic response.

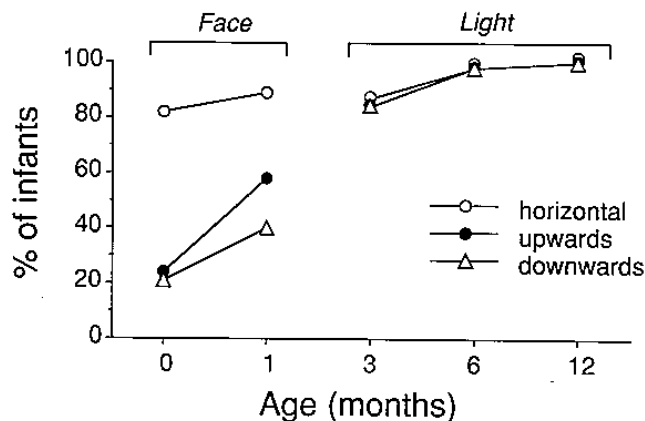


Figure 5: Refixation/saccadic response.

The responses to horizontal pursuit movements (Figure 2) and horizontal saccades (Figure 3) show a similar pattern. Of the neonates, 78% were observed to make a horizontal refixation of the examiner's face with no response to any of the other fixation objects, except the OKN drum. At 1 month of age, 87% demonstrated a horizontal following movement of the examiner's face and 89% a refixation movement. Only 2% showed a following movement to the penlight, none demonstrating a saccadic refixation response, with a slightly higher incidence of response to the visual object. Optokinetic nystagmus was demonstrated in 69% of neonates and 91% of 1 month infants. At 3 months of age 99% of infants demonstrated pursuit movements and 96% demonstrated saccadic refixation to a visual object. These figures were a little less when a penlight was used as the fixation object.

A comparison between the horizontal and vertical responses of pursuit and saccadic movements is shown in Figures 4 and 5, respectively. It can be seen that as neonates and at 1 month, horizontal movements are observed more frequently than vertical, with upwards movements more frequent than downwards movements. At 1 month, 87% of infants can be observed to make a horizontal following movement of the examiner's face, 59% an upwards and 42% a downwards movement. 89% of 1 month infants demonstrated a horizontal refixation saccade, 58% an upwards and 40% a downwards refixation.

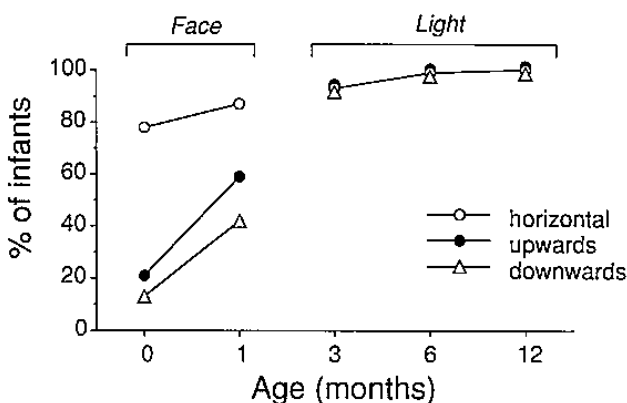


Figure 4: Pursuit/following response.

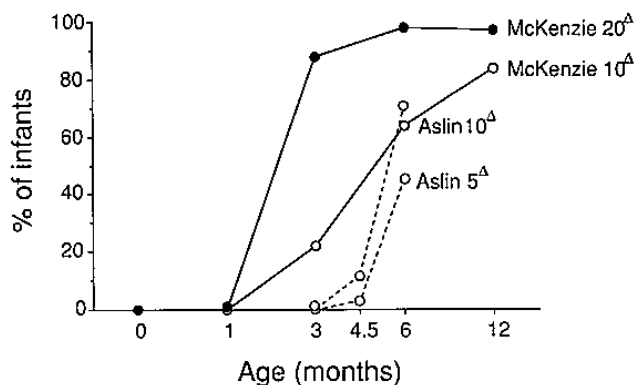


Figure 6: Percentage of infants giving positive prism fusion response.

response was observed in 22% and 88% of 3 month infants respectively, and in 64% and 98% of 6 month infants respectively.

DISCUSSION

The visual acuity, retinoscopy and ophthalmoscopy examination show that the visual development of these infants is within normal range.^{8,9}

It can be seen that the fixation responses of the neonates were similar to the results found by LaRoche and Anderson,⁴ showing that the majority of infants responded to the examiner's face by fixation, following and refixation, with only one infant showing any response to the penlight. At 1 month of age the results are similar, with only a small number of infants responding to stimuli other than the examiner's face.

Optokinetic nystagmus was elicited in a large proportion of the neonates, again showing a similar response to the study by LaRoche and Anderson.⁴ Kremenitzer et al¹ also state that OKN is a more potent stimulus than a single target in the responses of neonates. Of note is the stability of the frequency of a response to optokinetic nystagmus from 1 month of age.

The infants at 3 months show a dramatic change in response, with almost all the infants demonstrating pursuit and saccadic responses to each of the different stimuli. It is interesting to note that a "noisy toy" did not show an increased frequency of response to a "quiet toy". At this age an auditory stimulus did not result in a refixation saccade in most infants, only 36% looked towards the sound in a horizontal direction and 11% vertically. These figures are in contrast to the developmental sequence suggested by Erhardt¹⁰ who states that 3 month infants will turn their head and eyes towards the side of a sound.

The difference in responses of horizontal and vertical ocular movements is of interest. As detailed previously the horizontal responses, both pursuit and saccadic, appear to develop before the vertical responses, with horizontal responses much more frequently demonstrated than vertical movements. This is reported by Hainline,² but the frequencies are not cited. Of interest also is the apparent development of

upwards responses prior to downward responses. By 3 months of age these differences are no longer observed.

Pursuit movements were observed and were qualitatively assessed as smooth or jerky. All of the neonates and 1 month infants were recorded as having jerky pursuit movements. At 3 months, 39% of the infants still showed consistently jerky pursuit, whereas 60% showed an asymmetrical response where the movement was smooth on following a target from the periphery to the midline, but jerky on following from midline to periphery. This phenomenon is reported by Erhardt¹¹ Faragher and McLean¹² as a developmental pattern, but no physiological reasons are given to explain the observation. By 6 months of age, 98% of the infants demonstrated smooth following movements and this increased to 100% by 12 months. Various studies, both qualitative such as Barten et al,³ and quantitative such as Kremenitzer et al¹ and Hainline,² report that the latency for a pursuit movement in infants is increased and that smooth pursuit movement is interspersed with saccadic movements.

Another phenomenon reported as a developmental stage by Erhardt^{10,11} is the midline jerk. On observation for this phenomenon at each age group, a midline jerk was not observed when the infants were smoothly following and maintaining their fixation of the target. At the neonate, 1 and 3 month age groups when jerky pursuit movements were still observed, there appeared no difference at the midline.

Saccadic movements in young infants are reported as being hypometric and consisting of saccadic steps.^{2,7} This study would support the opinion that up until 6 months of age saccades appear hypometric, often observing 2 or 3 saccades to obtain fixation, and accompanied by head movements. At 6 and 12 months of age the majority of saccades qualitatively appear accurate.

As a binocular motor fusion response was clearly demonstrated in the majority of infants at 3 months of age using a 20 dioptr prism, the results of this study appear to support Aslin's hypothesis⁷ which suggests that a stimulus greater than 10 prism dioptr is required to elicit a

motor fusion response in infants prior to 4 months of age. It is of clinical interest that in 3 and 6 month infants a small fusion response is difficult to observe because of the large amounts of head, eye and body movements that occur when attempting a fusion reflex test, whereas a 20 dioptre prism gives a more easily observed and conclusive result.

CONCLUSIONS

In summary, it would appear that the best stimulus to use for assessment of a neonate or 1 month infant in the routine clinical environment is the examiner's face, where a reliable fixation or following horizontal movement could be observed in at least 80% of the infants. At this stage, no other stimuli, excepting optokinetic nystagmus and dolls head testing, will gain a reliable ocular motor response. Of clinical importance also is the delay in the development of vertical compared to horizontal eye movements.

In contrast, by 3 months of age infants are very attentive visually and will observe any fixation object. At this stage fixation, pursuit and saccadic responses, both horizontal and vertical, are expected from all infants, though a penlight may not be of interest to some infants and may not gain a response. At 3 months of age pursuit movements may still appear jerky and saccades inaccurate, but a response is obtained. All these infants demonstrated full convergence, and a fusion response can be elicited in the majority using a 20 dioptre prism.

At 6 and 12 months all the responses are demonstrable, pursuit movements appearing smooth, saccades accurate, convergence full and almost all demonstrating a positive 20 dioptre fusion response.

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