Evaluation of spatial discrimination performances of human newborns with the visual pursuit of pattern stimuli.

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Pursuit eye movements have been recorded from infants at birth, at 2 and 4 months during the presentation of stimulations specific of spatial discrimination functions. Stimulations were generated on a cathode ray tube placed 30 cm away from the baby. The stimuli were a square wave grating sustaining 9.4° of visual angle upon a uniform surface of equal mean luminance. The grating moved along a horizontal axis at a velocity of 7°/s. The mean luminance was 5 cd/m2 and the contrast 95%. Eye movements were recorded with the photo-oculographic technique which is based on the measurement of the position of the pupil center relative to the image of an IR source reflected on the cornea. The photo-oculograph includes a solid state camera mounted on a rotating turret above the head of the baby. A hot mirror is positioned on the screen to obtain by reflection the image of the eye. 120 full-terms infants have been examined. All subjects were between 1 and 9 days old. They were selected in alert inactive state. They were reexamined at 2 and 4 months. Four different spatial frequencies have been used ranging from 0.1 to 0.8 cpd at birth and from 0,2 to 3.2 cpd at the older age. The test is interpreted as followed if a visual pursuit was elicited during at least one crossing of the stimulator screen. The criteria of visual pursuit was based upon the correlation between the positions and velocities of the eye movements and the displacement of the stimulus.
A visual pursuit of at least one test was obtained in 72.5 % babies and in 100% 2 and 4 month old infants. Grating acuity was estimated as the highest spatial frequency which yielded a visual pursuit. Considering the number of infants submitted at each test, the distribution of results as a function of the stimulus spatial frequency are summarized in the following table.

	0.1 cpd	0.2 cpd	0.4 cpd	0.8 cpd	1.6 cpd	3.2 cpd
Birth	47.6	54.5	**76.5**	50	-	-
2 months	-	4.7	14.3	30.4	**37**	-
4 months	-	-	2	20.9	44	**63.6**

Visual pursuits have been also analyzed and they were found to be smooth for 13.6% at birth, for 38.1% at 2 months and 68.8% at 4 months. Visual pursuit of a stimulation specific of spatial discrimination is present at birth. Estimation of the grating acuity by recording visual pursuit are similar to those assessed though preferential looking. This method allows an rapid and objective measurement.

Poster ARVO 1993

Evaluation of spatial discrimination performances of human newborn infants with the visual pursuit of pattern stimuli.

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Several types of oculomotor responses have been observed at birth and have been used to evaluate the visual capacities in the human newborn: gaze orientation during the presentation of a stimulus (Fantz 1962), visual pursuit of a moving stimulus (Swarting 1954, Dayton 1964), and optokinetic nystagmus (Gormann 1957).

In a previous study, we used such stimulation for the study of visual pursuit in infants (Charlier et al, 1986, 1987). Eye movement analysis was based on direct viewing of the subject's eyes and on electro-oculographic (EOG) recordings. In a large number of subjects, the EOG recordings had been found unreliable due to contamination by electrode potential drift and head movements.

In the present study, we have used a more precise and reliable technique, based on the analysis of images of the eye. Recordings of pursuit eye movements during the displacement of a stimulus specific of spatial discrimination function have been made on infants at birth, at 2 and 4 months. The results have been analyzed to evaluate the evolution of spatial frequency discrimination and the maturation of smooth pursuit.

We used a procedure proposed by Millodot et al, to study the visual acuity (Millodot, 1969). This procedure consisted to elicit a pursuit movement by a moving grating and to characterize visual acuity by the threshold visibility angle of the pursued grating. Millodot used this technique on 107 adults and found a correlation of 0.84 with subjectively determined visual acuity.

Visual Stimulation

Stimulations were generated on a cathode ray tube placed 30 cm away from the baby. Two size of display screen were used subtending 70 by 50 degrees or 35 by 25 degrees at the subject's eye.

The stimuli were a vertical square wave grating upon a uniform gray surface of equal mean luminance. For the larger screen, the stimulus subtended 10 degrees and for the smaller 5 degrees. The grating moved along a horizontal axis at a constant velocity of 7 degree per second for the tests performed on newborns and 16 degrees/second for the older infants.

Four different tests have been used (Fig. 1) varying in spatial frequency between 0.1 to 0.8 cpd when the larger screen were used and between 0.2 to 1.6 cpd in the other case.

At birth and at 2 months the contrast was 95%. At 4 months, the contrast was reduced to 70% in order to reduce the spatial resolution performance of the subjects to a range which could be achieved by our instrument.

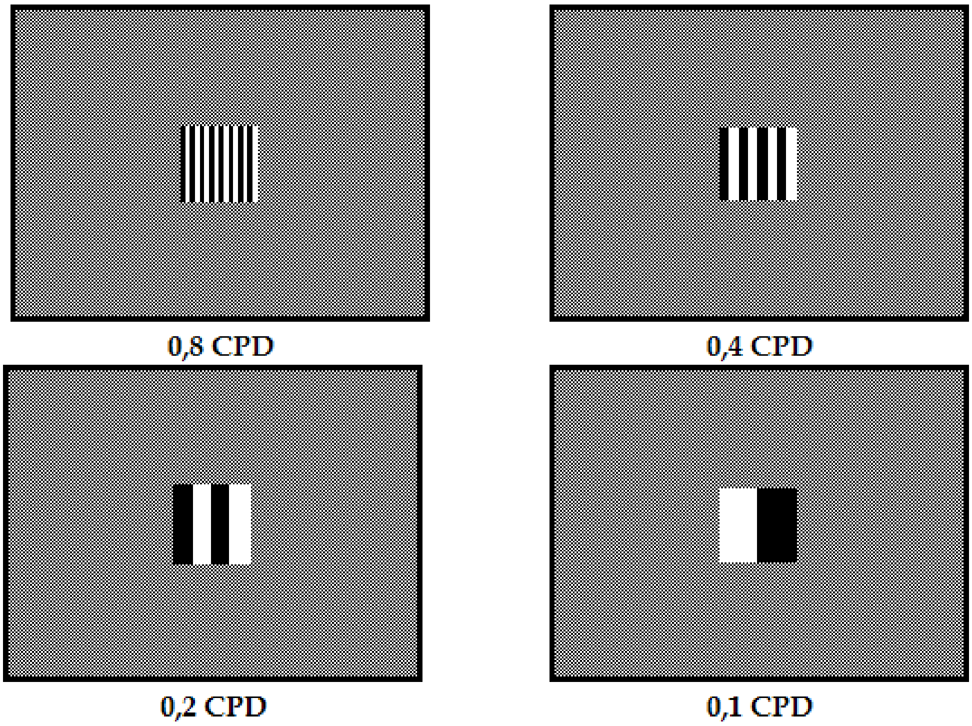

Fig. 1. - visual stimulus used during this study

		Large screen	Small screen
TEST	**Number of bars**	**Spatial frequency (cpd)**	**Spatial frequency (cpd)**
T1	**2**	**0.1**	**0.2**
T2	**4**	**0.2**	**0.4**
T3	**8**	**0.4**	**0.8**
T4	**16**	**0.8**	**1.6**

Tab 2 : Spatial frequency in function of the size of
the display screen for a 95% contrast

Eye movements recording equipment

Eye movements were recorded with the photo-oculographic technique (Charlier 1982 1986, Merchant 1974, Hainline 1982 1985) which is based on the measurement of the relative position of the corneal reflection and the pupil center.

The advantages of this technique for the examination of infants are numerous : measurements are independent from the head movements. They are absolute and precise in all gaze directions.

Data on X and Y eye position and pupil size were produced at 30 Hz and sent to a microcomputer for storage. The computer controlled stimulus presentations from trial to trial and also displayed the incoming real time eye position on a graphics terminal.

The set-up includes a solid state camera mounted on a rotating turret above the head of the baby. A hot mirror is positioned at the center of the cathode ray tube to obtain by reflection the image of the baby's eye (fig. 2).

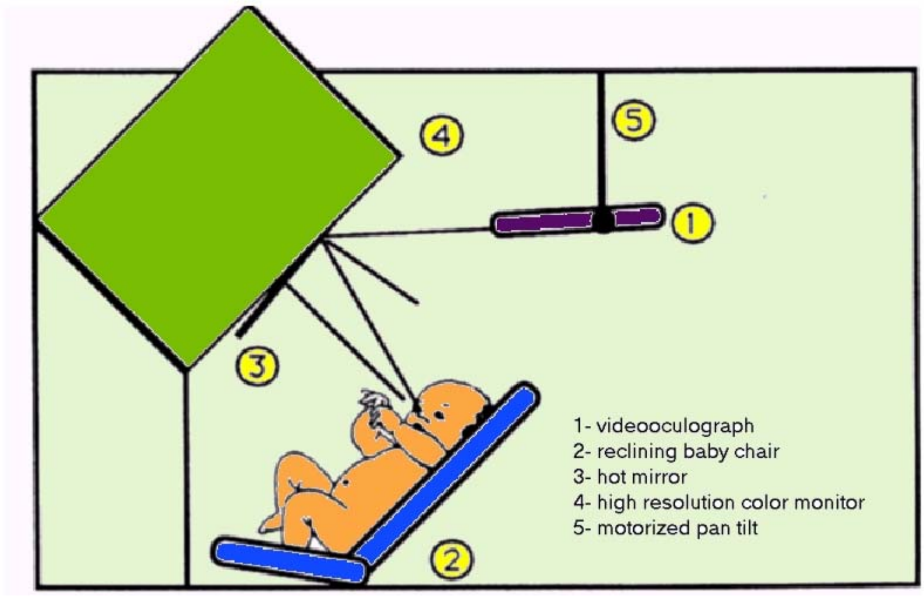

Fig. 2. - Optical set-up
(1- Photo-oculograph, 2- baby's reclining seat,
3- hot mirror,
4- cathode ray tube stimulator, 5- motorized camera mount)

Subjects

Three groups of infants were included in this study.

- The first group (0-M) consisted of 170 full-terms infants with postnatal ages from 1 to 9 days (mean 3.4). Most of them were solicited through letters mailed to parents to perform the same experiments at the age of 2 months and 4 Months.
- 45 infants returned at the age of two months (age ranging between 56 days and 68 days) and constituted our second group (2-M).
- The third group (4-M) consisted of 21 infants and were between 120 and 152 day old (mean 130).

All subjects have been examined at the obstetric clinic of Roubaix and were selected in alert inactive state characterized by open eyes and little body movement.

Procedure

The subjects were positioned facing the display screen seating in a baby's reclining seat. All viewing was binocular and an ascendant staircase procedure was used. Trials were a maximum of 30 seconds long but could be shorter if a pursuit was elicited faster.

The experimental conditions were not exactly the same for the three group and have been adapted in function of the age of each group in order to take into account the development of the spatial discrimination in infants. Differences are resumed in table 2.

Parameters	**group 0-M**	**group 2-M**	**group 4-M**
Velocity	8deg/s	16 deg/s	16deg/s
Display size	Large	Large for lower frequency and small for the others	Large for the lower frequency and small for the others one
Contrast	95%	95%	70%
First test	T2 (large) 0.2 cpd	T2 (large) 0.2 cpd	T3 (large) 0.4 cpd

Tab 2 - experimental conditions: differences between the three group

Evaluation of the recording technique

For the 0-M group (fig 3), reliable recordings of eye movements were obtained in 73.5% of the 170 subjects. 12.9% subjects did not cooperate sufficiently to provide an adequate measurement and for another 13.5%, recording were not suitable enough to be interpreted. For the 2-M group, all the recordings were found reliable and for the 4-M group, 2 infants (over 21) were uncooperative.

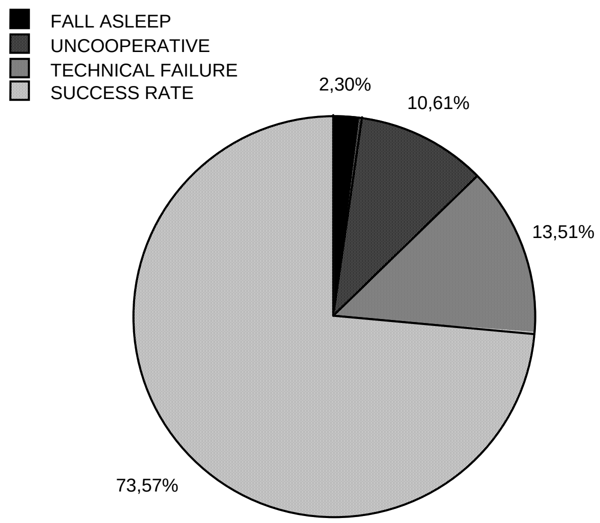

Fig 3 : Distribution of results obtained for the newborns group

Evaluation of spatial discrimination performance.

We hypothesize that the presence of a pursuit movement for a target of a given spatial frequency necessitates that the subject's visual system is able to resolve this spatial frequency.

Our criteria for visual pursuit were based upon the correlation between the horizontal and vertical positions and velocities of the eye movements and the displacement of the stimulus during at least one crossing of the screen.

Examples of some of the eye movements' recordings are presented in figures 4 to 9 which show eye position versus time for horizontal and vertical eye movements components. (time scale : 5000 ms/division)

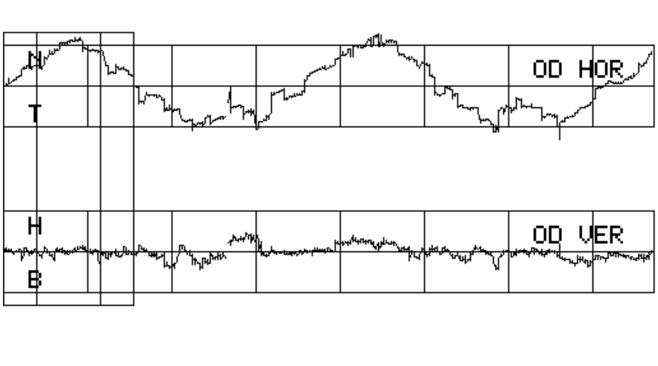

Fig 4 : Pursuit obtained from a 2 day-old during the presentation of a 0.4 cpd stimulus

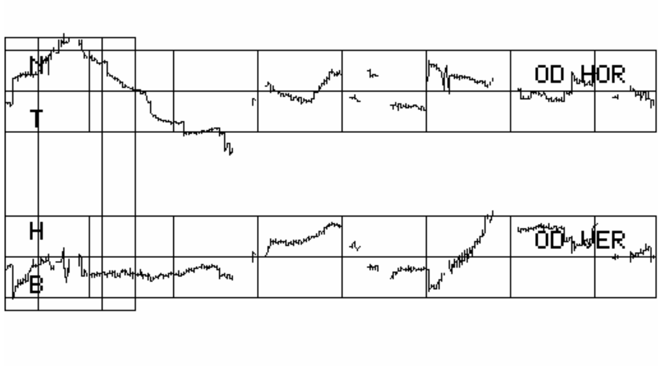

Fig 5 : Partial pursuit obtained from a 1 day-old during the presentation of a 0.2 cpd stimulus

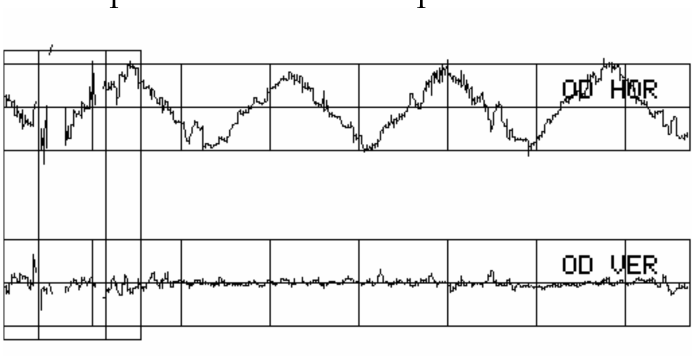

Fig 6 : Pursuit obtained from a 2-M old during the presentation of a 0.8 cpd stimulus

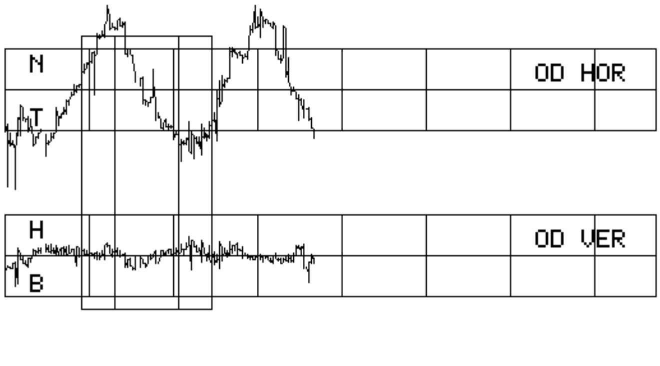

Fig 7 : Pursuit obtained from a 4-M old during the presentation of a 0.8 cpd stimulus (C70%)

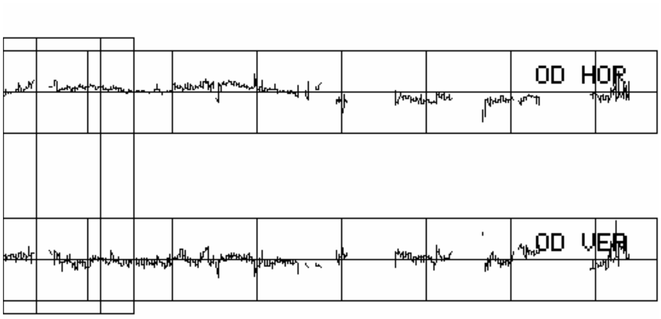

Fig 8 : Absence of pursuit

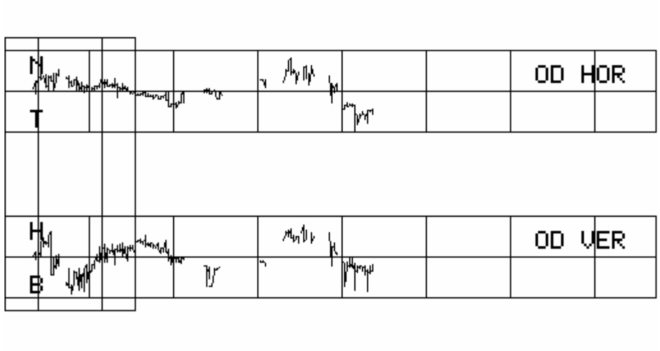

Fig 9 : Absence of pursuit

A visual pursuit of at least one test was obtained

- in 82,4% babies at birth,
- in 97,7% at two months
- in 100% at 4 months.

Grating acuity was estimated as the highest spatial frequency which yielded a visual pursuit. The distribution of results as a function of the stimulus spatial frequency is summarized in the following table.

For the 4-M group, we assume that a reduction of contrast to 70% resulted in a decrease by 50% of the spatial resolution performance

Considering the number of infants submitted at each test, the best scores (fourth column) were

- 0.4 cpd for the 0-M group
- 0.8 cpd for the 2-M group.
- 3.2 cpd for the 4-M group (contrast of 70%)

In the figure 10, the percentage of infants following each frequency was reported versus the spatial frequency in function of age. This figure shows that 50% threshold was obtained for

G 0.28 cpd at birth,
G 1.2 cpd at 2 month old
G 2.2 cpd at 4 month old (contrast 70%).

0-M GROUP

Spatial Frequency	Number of subjects tested	Number following	Best score	Best score (cumulated value)
0.8 cpd 95%	4	2 (50)	2 (50)	2 (1.6)
0.4 cpd 95%	34	28 (82.2)	**26 (76.5)**	28 (22.4)
0.2 cpd 95%	103	74 (73.3)	55 (54.4)	83 (66.4)
0.1 cpd 95%	42	34 (80.9)	20 (47.6)	103 (82.4)

2-M GROUP

Spatial Frequency	Number of subjects tested	Number of following	Best score	Best score (cumulated value)
1.6 cpd 95%	27	10 (37.03)	10 (37)	10 (22.7)
0.8 cpd 95%	37	35 (82.2)	**21 (56.7)**	31 (70.5)
0.4 cpd 95%	44	43 (97.7)	11 (25)	42 (95.5)
0.2 cpd 95%	43	43 (100)	1 (2.3)	43 (97.7)

4-M GROUP

Spatial Frequency	Number of subjects tested	Number following	Best score	Best score (cumulated value)
1.6 cpd 70%	12	7 (58.3)	**7 (58.3)**	7 (38.8)
0.8 cpd 70%	16	11 (91.7)	5 (31.2)	12 (66.7)
0.4 cpd 70%	18	17 (94.4)	5 (27.7)	17 (94.4)
0.2 cpd 70%	15	10 (66.6)	1(6.6)	18 (100)

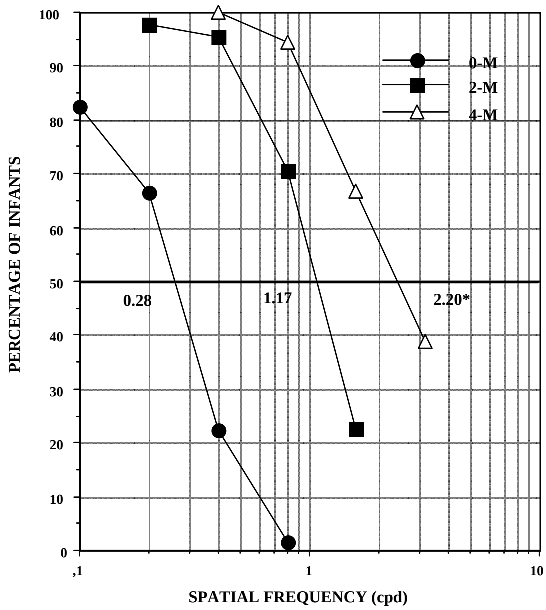

Fig 10 : Distribution of the best spatial resolution performance for the three age groups (0-M, 2-M, 4-M)

Evaluation of maturation of smooth pursuit.

Smooth pursuit is generally considered as specific of cortical processes. Most studies on visual pursuit of infants (Aslin 1981, Roucoux 1983) have concluded that smooth pursuit does not emerge until the end of the second postnatal month. To our knowledge, only one study (Kremenitzer, 1979) has reported that newborns show some brief instances of smooth following movements.

To investigate this aspect, we have scaled our recordings as smooth (fig 11), saccadic (fig 12) and combined if the recording included smooth pursuit interspersed with saccadic eye movements (fig 13).

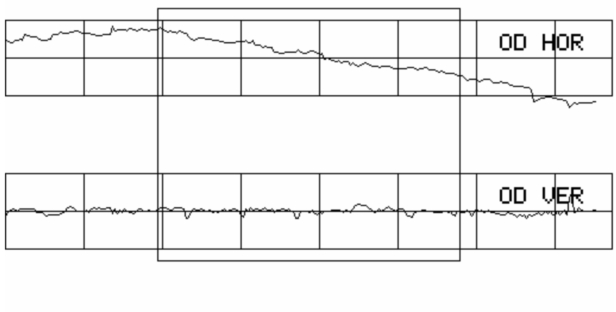

fig 11 : smooth

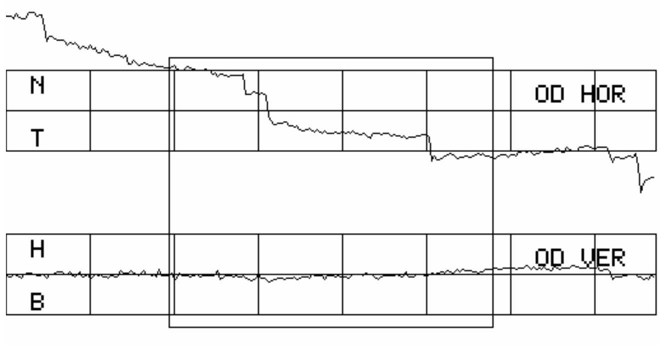

fig 12 : saccadic

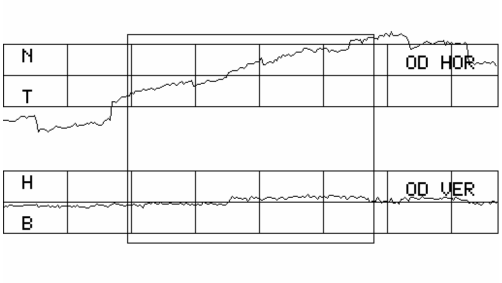

fig 13 : mixed

Distribution of the recordings in each category is given in function of age in figure 14.

Smooth pursuit ability improves obviously with age and the percentage of infants showing instances of smooth or combined pursuit rises to 42% up to 74,1%.

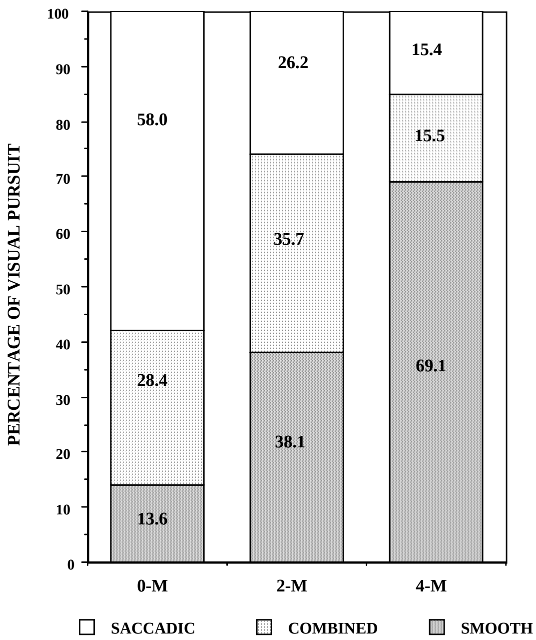

Fig 14 : distribution of the recordings in function of age

Our results on the spatial discrimination capacities in infants were:

- similar to those obtained with the preferential looking technique taking into account the physiological dispersion of the data and taking into account the luminance of the test (5cd/m2 - Dobson et al, 1983)
- and one octave lower than those obtained with the optokinetic nystagmus.

(see table 4 for a comparison with the data obtained on newborn and figures 15 and 16 for the evolution of grating acuity at different ages).

Authors	Technique	Number of subjects and age		Grating acuity (cpd)
Gorman et al 1957	OKN	100	< 5	**1,0 cpd** for 80%
Dayton et al 1964	OKN	32	< 8	**1,5 cpd** for 50%
Fantz et al 1962	PL	7	< 1	**0,60 cpd**
Miranda 1970	PL	-	< 3	**0,45 cpd**
Dubowitz 1983	PL	89	< 8	**0,37 cpd** for 95%
Brown 1986	PL	21	< 8	**0,63 cpd**

Tab 4 : Grating acuity of newborn infants (less than 8 days)
OKN : optokinetic nystagmus, PL : preferential looking

Our results concerning the improvement of the smooth pursuit ability with age are in agreement with the data found in literature.

However our result concerning the ability of newborn to pursue smoothly moving constant velocity targets seems to be inconsistent with the reports of Aslin (1981), Shea and Alsin (1984) Roucoux et al, (1983) etc...

These authors reported that smooth following do not emerge until the end of the second postnatal month. This inconsistency might be explain in part to

- the velocity of the tracking target (8d/s and16 d/s)
- the sizes of the stimulus (10 and 5 degrees)
- the duration of the smooth segments (fixed to 15% of the recording time)
- the use of a more accurate recording technique.

Resulting data from the estimation of the grating acuity by recording visual pursuit are related appropriately to the existing literature and are similar to those assessed though preferential looking.

These result is particularly important as the smooth pursuit is typically regarded as controlled by the brain stem and might be the result from the addition of cortical processing to signals received from lowers centers in the visual system. The orientating behavior used at the basis of the preferential looking has usually assumed to be voluntary and thus ascribed to higher centers. However, it is unclear what level of the visual system is responsible for the preferential behavior (Harris et al, 1987). `

For the OKN approach, a criticism we would raised is that the OKN is certainly associated to sub cortical structures.

In conclusion, the use of visual pursuit to characterize the spatial discrimination capacities in infants appears to be a good solution.

The recording technique based upon the measurement of the relative position of the pupil center and the corneal reflection allows a rapid and objective measurement. It is a reliable method for deriving grating acuity from uninstructable subjects such as infants.

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