Visual acuity in the first two years of life in healthy term newborns: an experience with the Teller acuity cards

Anna Cavallini*,**
Elisa Fazzi***
Viviana Viviani***
Maria Graziana Astori****
Silvia Zaverio****
Paolo Emilio Bianchi*****
Giovanni Lanzi******

* Department of Child Neurology and Psychiatry, IRCCS C. Mondino Institute of Neurology,
** University of Pavia
*** Department of Paediatrics, Civil Hospital of Voghera (PV)
**** Department of Ophthalmology, IRCCS S. Matteo Hospital, Italy

Reprint requests to: Prof. Elisa Fazzi
Department of Child Neurology and Psychiatry,
IRCCS C. Mondino Institute of Neurology,
via Palestro 3 - 27100 Pavia, Italy
E-mail: efazzi@unipv.it

Accepted for publication: May 15, 2002

Summary

Teller Acuity Cards are a new “preferential looking” procedure for the evaluation of visual acuity in newborns and infants. We used this test to assess, longitudinally, visual acuity in 60 healthy term newborns followed up from birth to two years of age. In order to have a set of comparison parameters for use in studies of newborns at risk of developing visual system impairment, the relative maturational curve was plotted. The acuity values of our sample are in line with those reported by other authors in the literature and they represent the first set of such data referring to a group of healthy term newborns in Italy. This paper provides a visual acuity curve for the first two years of life obtained from healthy term newborns, a curve which could prove useful for reference when this technique is used on newborns at risk of developing neurological and especially visual problems.

KEY WORDS: Follow-up, infants, Teller acuity cards, visual acuity.

Introduction

Assessment of sight is of great clinical importance in the first years of life. In recent years, new procedures have made reliable assessment of vision in infants possible. Visual acuity can be defined in one of three ways, depending on the type of stimulus used in its assessment: 1) “Detection Acuity”, the visible minimum or smallest detectable stimulus; 2) “Resolution Acuity”, the separable minimum, that is, the subject’s ability to perceive the separate elements of a stimulus made up of different parts (e.g., black and white stripes, or a “grid”); 3) “Recognition Acuity”, i.e. the subject’s ability to recognise letters, numbers or other symbols, as in optotype tables (1,2).

In recent decades, several methods have been developed in order to find a way of assessing visual acuity in newborns and infants: these have included both electrophysiological methods, such as visual evoked potentials (3,4) and behavioural methods, such as optokinetic nystagmus and “preferential looking” (5-10).

The “preferential looking” technique is based on observation of the reaction of newborns and infants when faced with different visual stimuli (11). Spontaneous behavioural reactions on the part of the child, i.e., gazing, turning of the head towards the stimulus, and eye movements, are all indicators of his or her response. The aim is to determine the child’s visual-perceptive threshold through observation of his reaction to the stimuli presented.

The Teller Acuity Cards (12) represent the latest version of the “preferential looking” technique. Developed on the basis of studies conducted by a number of authors (13-24), these cards can be considered preferable to other “preferential looking” tests and other methods, such as optokinetic nystagmus and visual evoked potentials. Teller Acuity Cards can be applied to a wide range of subjects in terms of age (from birth throughout the preschool period); they are quick and simple to use and extremely reliable.

The aims of our study were 1) to assess the development of visual acuity through Teller Acuity Cards in the first two years of life, and to plot the relative maturational curve, investigating ways in which this technique may be used to complete the anamnestic and clinical data gathered during neurological examination; and 2) to obtain a set of comparison parameters for use in studies of newborns at risk of developing visual system impairment.

Materials and methods

Our study group was made up of 60 healthy term newborns (34 female and 26 male) born consecutively at the hospital of Voghera between February 15th and March 30th, 1993. The average birthweight of our sample was 3269.1 g (± 431.2 g).

The newborns were selected according to Prechtl’s op-
timidity criteria. The Apgar index in all the newborns was ≥ 8 at 1 and 5 minutes. We gathered the following information in relation to all the newborns:

1) personal and general paediatric data;
2) anamnestic data;
3) results of clinical tests carried out during their hospital stay.

In the first week of life, all the infants underwent a neurological examination (Amiel Tison and Grenier) and an assessment of binocular visual acuity (Teller Acuity Cards).

Visual acuity assessments were carried out between 5 hours and 6 days postpartum, and 90-120 minutes after the last feed, in order to avoid excessive drowsiness or fretfulness. The tests were performed in a quiet environment with appropriate conditions in terms of temperature and lighting. Acuity Cards are illuminated by diffuse and indirect daylight (mean luminance ranged from 12 to 16 cd/m²) (12,23).

After discharge from the department of neonatology, each subject was examined by the same child neuropsychiatrist at three, six, nine, twelve, eighteen and twenty-four months of age (± 5 days). Each follow-up examination included:

- an updating of the anamnestic data;
- a neurological assessment, according to Amiel Tison and Grenier;
- an assessment of visual acuity using the Teller Acuity Cards.

Furthermore, the follow up at 18 months of age also included an assessment of psychomotor development using Bayley’s Scales of Infant Development and an ophthalmological assessment.

Follow-up examinations, too, were conducted in the environmental conditions outlined above.

Visual acuity was assessed by two investigators who took it in turns to administer the test, and who had received specific training prior to the start of this research.

The visual stimuli used were 17 rectangular cards (25.5 x 51 cm) each of which had a hole in the middle. On each card, there was a square (15.5 x 15.5 cm) made up of vertical black and white stripes (“grid”), which had the same luminescence as the rest of the card. The spatial frequency of the “grids”, (i.e., the number of black and white bands/centimetre), ranged from 38.0 to 0.32 cycles/cm (one cycle being a combination of one black plus one white line).

There was a difference of 1/2 an octave between one card and the next (an octave is a halving or doubling of a spatial frequency; in other words, if we take, for example, the card with a spatial frequency of 3.2 cy/cm, the subsequent one will have a spatial frequency of 4.8 (i.e., 3.2+3.2/2) and the previous one will have a spatial frequency of 1.6 (i.e., 3.2-3.2/2)) (12).

At birth the infants were held in the investigator’s arms during the test, while at subsequent tests they were held by their parents.

The investigator presents the cards at the child’s own height and at a distance which varies according to the age of the child (38 cm up to six months of age, 55 cm from seven months to three years of age, and 84 cm from three years of age upwards). The investigator does not know on which side of the card the black and white ‘grid’ is located, and ascertains its position from the preferential looking behaviour displayed by the child (gazing at the target, or turning the head). He then repeats the test presenting the stimulus from the other side, turning the card through 180°. Lastly, he looks at the card to see which side the pattern is on and whether he has judged correctly (Fig. 1).

Visual acuity is calculated on the basis of the grid which, of those seen by the child, has the highest spatial frequency. The value expressed in cycles per centimetre is transformed into cycles per degree of visual angle (cy/deg) using the following formula: (distance x cycles per cm) /55 (12).

When assessing visual acuity the “confidence” of the investigator, (i.e., his level of certainty that a given grid, with a given spatial frequency, has been seen by the subject under investigation) is taken into account. The examiner’s “confidence” is his or her subjective judgment and it is independent of the time needed to obtain preferential looking. If preferential looking is obtained only once, and therefore without confirmation being obtained by rotating the card through 180°, the relative spatial frequency is not attributed and the previous card is re-administered. The investigator’s ‘confidence’ is expressed numerically by scores of 5 (maximum) to 1 (minimum) inclusive. A level of “confidence” equal to, or better than, 3 is deemed acceptable.

Another factor taken into consideration is “compliance”, i.e., the reliability of the test defined according to how cooperative the child is. A test is defined as “highly reliable” if the child collaborates fully; in other words, if he is attentive and participates and cooperates for the entire duration of the test; meanwhile, if the opposite is true, the test is deemed unreliable.

When the test is carried out completely and correctly, with no changes being introduced in the procedure, and when the child has responded clearly and unequivocally, the level of reliability of the test is considered “high” and the investigator is thus sufficiently sure that the result obtained corresponds to the child’s real threshold. If, on the other hand, the child does not cooperate sufficiently, the level of reliability of the test is defined as low, and while the visual acuity value is taken to be the best that could be obtained, it is recognised that it does not necessarily correspond to the child’s real threshold.
Results

All the members of the study group (100%) attended the follow-up checks scheduled for the first year, and 91.7% completed the entire programme of follow-up checks, until the age of 24 months. At each assessment, neurological development was found to be normal in all subjects. Psychomotor development, assessed at 18 months of age using Bayley’s Scales of Infant Development, revealed development quotients (both in the mental and motor scales) which, in all subjects tested, proved to be appropriate for the age of the child. Ophthalmological examination (at 12-18 months) revealed no clear refractive errors or squint in any subject. At each time point we obtained a Gaussian distribution of spatial frequency values for visual acuity.

Table I details the ages at which the subjects underwent the test, the number of children tested each time, and the number of test failures (i.e., the number of children who could not undergo the test due to excessive drowsiness, distress or liveliness). The next column gives, in relation to each occasion on which the tests were administered, the average visual acuity value, calculated on the basis of the entire sample; this value is expressed in cycles per degree. In addition, the relevant standard deviations expressed in octaves are given alongside in brackets. Table I also details the number and percentage of children whose tests were given “high” or “low” reliability scores. Types of behaviour likely to induce the investigator to consider a child’s test to be unreliable were excessive drowsiness, distress and refusal to be comforted and, in the later stages, distraction owing to his interest in the environment and in the people surrounding him. Mean visual acuity values in the last column refer to the tests judged to be “highly reliable” (in other words, excluding all assessments in which the investigator could not be sure that the last card seen effectively corresponded to the child’s real level of visual acuity), and of these “highly reliable” tests the averages in cycles per degree are calculated in relation to each age at which the test was administered, and the relative standard deviations are given. This calculation was made in order to assess whether there emerged significant differences in relation to the average visual acuity values detailed in the previous column (calculated from the values of all the children in the sample).

The degree of certainty on the part of the investigator as to the child’s response (i.e. “confidence”) was good in all the tests administered as part of this survey; confidence levels of 4 or 5 were obtained in all but two tests (performed at three months of age) and in these two cases the confidence level was 3. The maturational visual acuity curve obtained on the entire sample is presented in Fig. 2.

When the average visual acuity values of the whole sample are compared with those of the “highly reliable” group, it is found that the values of the latter group are never more than two standard deviations lower than those of the former.

Detailed below are the average binocular visual acuity values obtained from the whole sample and transformed into tenths in order, from a clinical point of view, to facilitate immediate comprehension: at birth 1.39 cy/deg (± 0.57) -0.5/10-, at 3 months 3.24 cy/deg (± 0.62) -1/10- at 6 months 5.43 cy/deg (± 0.43) -2/10-, at 9 months 9.38 cy/deg (± 0.29) -3/10-, at 12 months 11.05 cy/deg (± 0.35) -4/10-, at 18 mths 11.78 cy/deg

Table I - Mean values of binocular visual acuity in the first two years of life in 60 healthy infants born at term

<table>
<thead>
<tr>
<th>age</th>
<th>no. of infants</th>
<th>no. of failures</th>
<th>Tot. Mean VA ±SD</th>
<th>L.C.</th>
<th>H.C.</th>
<th>VA H.C. Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>birth</td>
<td>60</td>
<td>7/60 (11.6%)</td>
<td>1.39±0.57</td>
<td>8 (15.1%)</td>
<td>45 (84.9%)</td>
<td>1.53 ± 0.47</td>
</tr>
<tr>
<td>3 months</td>
<td>60</td>
<td>1/60 (1.7%)</td>
<td>3.24 ± 0.62</td>
<td>9 (15.2%)</td>
<td>50 (84.8%)</td>
<td>3.34 ± 0.56</td>
</tr>
<tr>
<td>6 months</td>
<td>60</td>
<td>/</td>
<td>5.43 ± 0.43</td>
<td>11 (18.3%)</td>
<td>49 (81.7%)</td>
<td>5.93 ± 0.34</td>
</tr>
<tr>
<td>9 months</td>
<td>60</td>
<td>/</td>
<td>9.38 ± 0.29</td>
<td>7 (11.7%)</td>
<td>53 (88.3%)</td>
<td>9.92 ± 0.19</td>
</tr>
<tr>
<td>12 months</td>
<td>60</td>
<td>/</td>
<td>11.05 ± 0.35</td>
<td>5 (8.3%)</td>
<td>55 (91.7%)</td>
<td>11.65 ± 0.23</td>
</tr>
<tr>
<td>18 months</td>
<td>54</td>
<td>1/54 (1.8%)</td>
<td>11.78 ± 0.29</td>
<td>10 (18.5%)</td>
<td>44 (81.5%)</td>
<td>12.08 ± 0.31</td>
</tr>
<tr>
<td>24 months</td>
<td>55</td>
<td>3/55 (5.4%)</td>
<td>21.08 ± 0.61</td>
<td>9 (16.4%)</td>
<td>46 (83.6%)</td>
<td>23.28 ± 0.63</td>
</tr>
</tbody>
</table>

Abbreviations: VA = visual acuity; L.C. = low compliance; H.C. = high compliance. Mean values are expressed in cy/deg and standard deviation in octaves.
The transformation into tenths is not recommended in the literature (12,26) as, using Teller Acuity Cards, it is possible to measure “resolution” acuity, while the measurement in tenths really refers to “recognition” acuity. However, as we mentioned above, this transformation is tolerated because the value in tenths is more immediately and more easily understood.

The entire test lasts for an average of 3 minutes (1-6 minutes). The longer time needed to administer the test to newborns was due to the tendency of such young infants to fall asleep. The time needed for subsequent tests was noticeably shorter.

In Table II we compare the results of studies in the literature with those obtained from our study.

Discussion

The assessment of vision in early infancy is of great importance due to the role it plays in a child’s development; vision is involved particularly in a child’s perceptive, motor and mental evolution. Visual acuity assessment techniques have been found to be the most suitable in order to obtain a reliable survey of the visual function in very early infancy, i.e., in newborns and young babies. The last decade has seen the development of a number of techniques, both electrophysiological (Visual Evoked Potentials) and behavioural (Optokinetic Nystagmus, “Preferential Looking” and “Forced-Choice Preferential Looking”). Of the latter, in particular due to the easy administration of the test, the Teller Acuity Card method has been found to be the best for assessing visual acuity in a clinical setting, and on a large scale (27-32).

We set out to ascertain how the Teller Acuity Cards could be used in a group of healthy children followed up from birth to the age of 2, in order to obtain data that could be used for comparison with findings relating to groups of newborns at risk of developing visual deficits. As has already been reported in other studies of healthy newborns and young babies (10,15,16,19,21,33,34), the visual acuity values obtained using the Teller Cards can be compared with those obtained using the other behavioural-type procedures, “Preferential Looking” and “Forced-Choice Preferential Looking”, which are unsuitable for use in clinical settings owing to the length of time needed to administer them. Our experience supports previous findings regarding the practicality, the high reliability, and the ease of application of these cards, and thus favours their use in clinical settings.

It is important to pay particular attention to the results viewed in the light of the “confidence” and “compliance” values recorded. At all ages in which the test was administered, the “confidence” values were always good: in the presence of high “confidence” values (4 and 5) it is seen that children, when faced with a black and white patterned stimulus and a plain stimulus which has the same luminescence, demonstrate a clear, unequivocal, and therefore easily identified preference for the former.

As far as “compliance” is concerned, (i.e., the level of cooperation of the child during the administration of the test), it can be seen from Table I that the percentage of “unreliable” tests was low at all ages investigated. Furthermore, no statistically significant difference emerged in relation to any of the ages tested when the average visual acuity value of the whole study group was compared with that of the “highly reliable” group, as none of the average visual acuity values obtained from the latter group was ever any more than two standard deviations lower than the averages recorded from the entire sample.

The time needed to administer the test, in our survey, was found to range from 1 to 5 minutes (excluding tests administered to newborns who, tending to fall asleep, required longer – up to a maximum of 6 minutes). This finding is in accordance with the above-mentioned studies (12).

In relation to nearly all the ages tested, the average visual acuity values are similar to those reported in the literature (Table II). As far as both average values and
standard deviations are concerned, our results coincide with those of the authors quoted in Table II. It is important to note that the comparison with McDonald’s data is not to be considered significant as the difference between the cards used in this author’s study was 1 octave and not 1/2 an octave as in our and other studies, a point which is also stressed by Mohn and van Hof-van Duin (16).

In conclusion, Teller Acuity Cards were found to be a useful instrument for assessing vision in non-collaborating subjects such as newborns and very young babies (35). This paper provides a visual acuity curve for the first two years of life obtained from healthy term newborns, a curve which could prove useful for reference when this technique is used on newborns at risk of developing neuropsychic and, particularly, visual problems (36).

Acknowledgments

This study was funded by an Italian Health Ministry grant, RF1992

---

**Table II - Binocular visual acuity in the first two years of life**

<table>
<thead>
<tr>
<th>Age</th>
<th>Author (ref. no)</th>
<th>Mean values of binocular visual acuity (cy/deg)</th>
<th>SD (octaves)</th>
</tr>
</thead>
<tbody>
<tr>
<td>newborns (&lt;7days)</td>
<td>19</td>
<td>1</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.7</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>1.5</td>
<td>/</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>1.4</td>
<td>0.6</td>
</tr>
<tr>
<td>1 month</td>
<td>14</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>1.3</td>
<td>1</td>
</tr>
<tr>
<td>2 months</td>
<td>14</td>
<td>2.1</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>2</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>1.4</td>
<td>0.7</td>
</tr>
<tr>
<td>3 months</td>
<td>16</td>
<td>4.1</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>3.2</td>
<td>0.6</td>
</tr>
<tr>
<td>4 months</td>
<td>14</td>
<td>3.7</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>4.5</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>4.9</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>6.5</td>
<td>/</td>
</tr>
<tr>
<td>5 months</td>
<td>10</td>
<td>4.3</td>
<td>0.9</td>
</tr>
<tr>
<td>6 months</td>
<td>14</td>
<td>4.7</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>5.3</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>7.8</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>5.4</td>
<td>0.4</td>
</tr>
<tr>
<td>8 months</td>
<td>18</td>
<td>9</td>
<td>/</td>
</tr>
<tr>
<td>9 months</td>
<td>10</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>9.6</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>9.8</td>
<td>/</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>9.4</td>
<td>0.3</td>
</tr>
<tr>
<td>12 months</td>
<td>10</td>
<td>6.3</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>10.2</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>13</td>
<td>/</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>11</td>
<td>0.3</td>
</tr>
<tr>
<td>18 months</td>
<td>10</td>
<td>9.8</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>10.7</td>
<td>0.5</td>
</tr>
<tr>
<td>24 months</td>
<td>10</td>
<td>14.9</td>
<td>0.6</td>
</tr>
</tbody>
</table>

*Functional Neurology 2002; 17(2): 87-92*
References