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INFANT VEP ACUITY MEASUREMENTS: ANALYSIS OF INDIVIDUAL DIFFERENCES AND MEASUREMENT ERROR [1]

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Summary The reliability of visual evoked potential (VEP) measurements of acuity was determined by estimating acuity for sinewave luminance gratings which were counterphase modulated at either 12 or 20 reversals/sec (rps). Gratings were swept in spatial frequency beyond the acuity limit and acuity was estimated from an extrapolation based on the last peak in the VEP amplitude versus spatial frequency function. Twenty-five infants ranging in age from 17 to 25 weeks were studied.

Individual 10 sec sweeps resulted in records with a criterion response in 65–75% of trials. The reliability of acuities obtained from individual 10 sec sweeps was ±0.54 octaves at 95% confidence across 12 and 20 rps recording conditions (RMS error of ±0.27 octaves). The best acuity attained by each infant on either a single sweep, or on their vector average, was reliable to ±0.38 octaves at 95% confidence (RMS error of ±0.19 octaves) compared to a range of individual acuities of about 2 octaves. Much of the variability of sweep VEP acuity in cross-sectional samples of infants is therefore attributable to reliable individual differences rather than to measurement error. In testing individual infants our analysis indicates that choice of temporal frequency accounts for only 14% of the variation in acuity estimates within subjects.

Keywords: *grating acuity — visual acuity — visual evoked potentials — human infants*

While a number of studies have used the visual evoked potential (VEP) to measure the development of pattern resolution in infants (Marg et al. 1976; Harter et al. 1977; Pirchio et al. 1978; Sokol 1978; De Vries-Khoe and Spekreijse 1982), an analysis of the error associated with such acuity measurements in individual infants has yet to be presented. This is most easily accomplished as an analysis of repeated measures, in this case, of acuity. Previous evoked potential studies have in some instances measured acuity in the same infant longitudinally (Marg et al. 1976; Harter et al. 1977; Pirchio et al. 1978; Sokol 1978) but none have reported test/retest reliability in the same infants within a session or across closely spaced sessions. An analysis of this type is important both in establishing the reliability of VEP measurements in individual infants and in determining the normal range of individual variation in the acuity estimate.

We have recently developed a rapid method of measuring VEP acuity (Norcia and Tyler 1984, 1985) based on discrete Fourier analysis of the steady-state evoked potential. Counterphase modulated luminance gratings are swept in spatial frequency from well below the acuity limit to well above it in 10 sec trials. Swept parameter techniques for measuring VEP thresholds have been used previously by Regan (1973, 1974, 1975), Tyler et al. (1979) and Sieple et al. (1984). In our version, each sweep trial lasts 10 sec, and as many as 12–20 acuity measurements can be made in a single session with a cooperative infant. It is thus generally possible to obtain 3–4 trials in a given stimulus condition and to test 3 or 4 conditions in each session. Our method for estimating grating

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acuity from the sweep record is to use linear extrapolation to zero amplitude of the highest spatial frequency peak in the VEP amplitude versus spatial frequency function, based on previous work by Sokol (1978) and Tyler et al. (1979).

Several possible procedures for assigning an acuity value arise when more than one estimate is available and a substantial degree of non-stationarity is expected. With the sweep technique it is often possible to obtain significant evoked responses on single 10 sec sweep records. To assign an acuity, one can choose the best extrapolated acuity for single trials or use some measure of central tendency of the individual trial extrapolations. Alternatively, an acuity estimate can also be made on the basis of a vectorial average of signal amplitudes from individual 10 sec trials. In a vector average, the phase reference of the individual trials is the same from trial to trial. Averaging n trials with the same phase reference results in an effective epoch length that is n times longer than the individual trials, yielding a reduction of noise power in the analysis by *root* n if the system under test is stationary and the noise is white. The vector average record can then be used as the input to the extrapolation procedure, to obtain an acuity estimate based on all the available records.

The VEP acuity for a condition has, in practice, been regarded (Norcia and Tyler 1984, 1985) as the highest value of either the single run with the best acuity or the acuity obtained by vector averaging all runs taken on that condition. The rationale for this procedure has been that variability in infant attentiveness, muscle activity and accommodative state can all conspire to lower the measured acuity, but cannot raise it if an adequate statistical criterion is applied. Thus using the highest acuity rather than, for example, the average acuity over several repeated measures, gives a better approximation of the *limiting* capabilities of the infant's visual system under the conditions of the test. Using the best acuity obtained from either single trials or their vector average also gives the most opportunities of being able to assign an acuity value.

The reliability of individual sweep extrapolations can be determined by examining the spread of acuity estimates for multiple measurements taken under the same stimulus conditions. The reliability of the single best acuity value in a given condition can be estimated by comparing the repeatability of acuity measurements taken under different conditions, such as the temporal frequency of the counterphase reversal, which produce similar mean acuities across a group of infants. The reliability of the acuity measurements using this procedure is compared below to the reliability of individual trials from the same condition. In performing this analysis we have found that the range of measurement error is small in absolute terms and that it is also considerably smaller than the range of acuities seen across infants in a cross-sectional sample. Our results thus indicate the existence of reliable and substantial individual differences in the estimates of VEP acuity.

Method and Material

Subjects

Infants were solicited for participation from parent education classes. The purpose of the experiment was explained to the parents and informed consent was obtained. Infants with eye turns or pathologies as noted by pediatricians were excluded, as were infants whose birthdate was not within 2 weeks of term. The present sample consisted of 25 infants between 17 and 25 weeks of age (mean age 21.3 weeks, S.D. ± 2.03 weeks).

Procedure

Infants were presented with sinusoidal luminance gratings of 80% contrast at a space-average luminance of 80 cd/m^2. The gratings were square-wave alternated in counterphase at 12 or 20 reversals/sec (rps) and simultaneously swept in spatial frequency over a range spanning the measured acuity. The gratings were presented in the vertical orientation on a 12 in. video monitor with a P4 phosphor and a 60 Hz interlaced frame rate. They were generated by a function generator, the output of which was mixed with composite video synchronization signals. The display system maintained full contrast to at least 100 c/screen (10 c/deg at 131 cm).

The spatial frequency of the reversing grating was incremented linearly every 0.5 sec during each 10 sec sweep to yield 20 equally spaced test points from which 19 VEP amplitude and phase measurements were eventually derived. The range of the spatial frequency sweep was generally 1–20 c/deg at a viewing distance of 131 cm or 2–40 c/deg at 262 cm. Field sizes were 10 and 5° at 131 and 262 cm respectively. Sixteen infants were run at 131 cm, 6 at 262 cm, 2 at both 131 and 262 and 1 infant at 65.5 cm. Testing distance was keyed to the infant's age and the experimenter's judgment of the infant's relative maturity for its age. We attempted to place the infant at a distance which would result in the acuity limit being reached near the middle of the 10 sec trial to minimize attentional demands and the small effects of monitor contrast roll-off beyond 100 c/screen.

VEP acuities were obtained at 2 square-wave reversal frequencies, 12 and 20 rps. These frequencies were selected to be comparable with the temporal conditions used by previous investigators (Pirchio et al. 1978; Sokol 1978) enabling a comparison to be made of acuities obtained using the sweep method with acuities obtained by testing spatial frequencies one at a time. The 12 rps condition should give nearly optimal acuities because Moskowitz and Sokol (1977) have shown that the infant's evoked response to pattern alternation reaches a peak in the 10–14 rps region for fine resolution targets, independent of age. We also wished to explore the higher frequency (20 rps), since other work indicated the presence of considerable signal amplitudes at higher frequencies (Norcia and Tyler 1984).

The procedure was to attempt at least 3 but no more than 6 trials before moving to a new condition. It was not always possible to obtain 3 replications due to the infants' limited cooperation. For the present study, we required that at least 2 replications per condition have been attempted, with at least one sweep or the average of the sweeps producing a criterion signal. The two temporal alternation rates were presented in a loosely randomized order together with 2 other temporal frequency conditions used for a separate study, for a maximum of 4 experimental conditions per subject in a session. Fixation was maintained during the trial with a small noisy toy dangled 1–2 cm in front of the display.

Recording conditions and spectrum analysis

The evoked response was recorded from a bipolar derivation of 1 cm above the inion versus 3 cm to the right of the midline at the same level. The EEG was amplified by amplifiers and filtered at 3 and 100 Hz corner frequencies (-3 dB points). Additional gain stages were included in the hardware interface and in the Analog Devices 284-J isolation amplifier.

The EEG was digitized at 200 Hz and a discrete Fourier transform over a 1 sec rectangular window (-3 dB bandwidth of 0.89 Hz) was performed by an Apple II+ microcomputer equipped with a hardware multiplier. The responses are plotted below as the mean amplitude (modulus of the transform) and phase over the 1 sec window, with the datum points plotted at the mean spatial frequency for each window. Each 1 sec bin contains the response from two spatial frequencies presented for 0.5 sec each, and is therefore 50% correlated with each adjacent bin. There are thus 19 datum points plotted for each spatial frequency sweep. The EEG noise amplitude during the trial at an adjacent temporal frequency of either 14 or 22 Hz is plotted in Figs. 1–3 as the open boxes for the 12 and 20 rps stimulation conditions respectively. The dotted line represents the mean amplitude over the 10 sec trial at the adjacent noise frequency. Both the response frequency and the auxiliary noise frequency were integer submultiples of the analysis epoch to avoid spectrum leakage through the window sidelobes.

The lower panels in Figs. 1 through 3 plot the response phase in radians over a range of 2π. Phase lag is indicated by a positive slope in the phase contour. Breaks in the phase plots occur at the modulus boundaries where the phases are plotted as both $+\pi$ and $-\pi$. A continuous phase contour can be visualized by shifting a segment of the phase contour by 2π so that the contours match.

Acuity was estimated by extrapolation to 0 μV of the last peak in the VEP amplitude versus spatial frequency function (Tyler et al. 1979; Norcia and Tyler 1985). A linear regression line was fit to the data between the last spatial frequency peak and the point at which the amplitude at the signal frequency dropped below the average noise amplitude. A scorable spatial frequency peak was defined as the highest spatial frequency peak on which the amplitude of the response exceeded 3 times the average amplitude during the trial at 14 Hz or 22 Hz for the 12 and 20 rps stimulus alternation frequencies respectively. Additionally the phase of the response during a spatial frequency peak had to be either constant or gradually lagging the stimulus. Any portion of the record in which the phase of the response showed a progressive phase lead with increasing spatial frequency was not scored. Further details of the recording method and analysis criteria used are presented elsewhere (Norcia and Tyler 1985).

Results

VEP amplitude versus spatial frequency functions for several infants are presented to show the range of acuity retest variation and the variety of spatial tuning functions which gave rise to the estimates of acuity.

Fig. 1 shows data for a 20-week-old infant (Stephanie) taken at 12 and at 20 rps. The data in Fig. 1a and b were taken at a viewing distance of 131 cm at 12 and 20 rps respectively while the data in c were taken at 262 cm and 20 rps. Note the linear spatial frequency abscissa, which optimizes resolution in the acuity region. The spatial frequency tuning functions (solid line, upper panels) each show a peak response near 2 c/deg and estimated acuities of 9.7, 8.0 and 9.7 c/deg respectively. In this infant, the form of the spatial tuning function and the acuity limits were quite similar over temporal frequency (Fig. 1a and b) and viewing distance (which also varied field size, Fig. 1b and c). The effect of field size was not systematically investigated since it has been shown that only a small retinal region contributes to the infant's high spatial frequency response (Spinelli et al. 1983).

Fig. 2 shows data for 2 infants whose spatial tuning functions are different at the two temporal

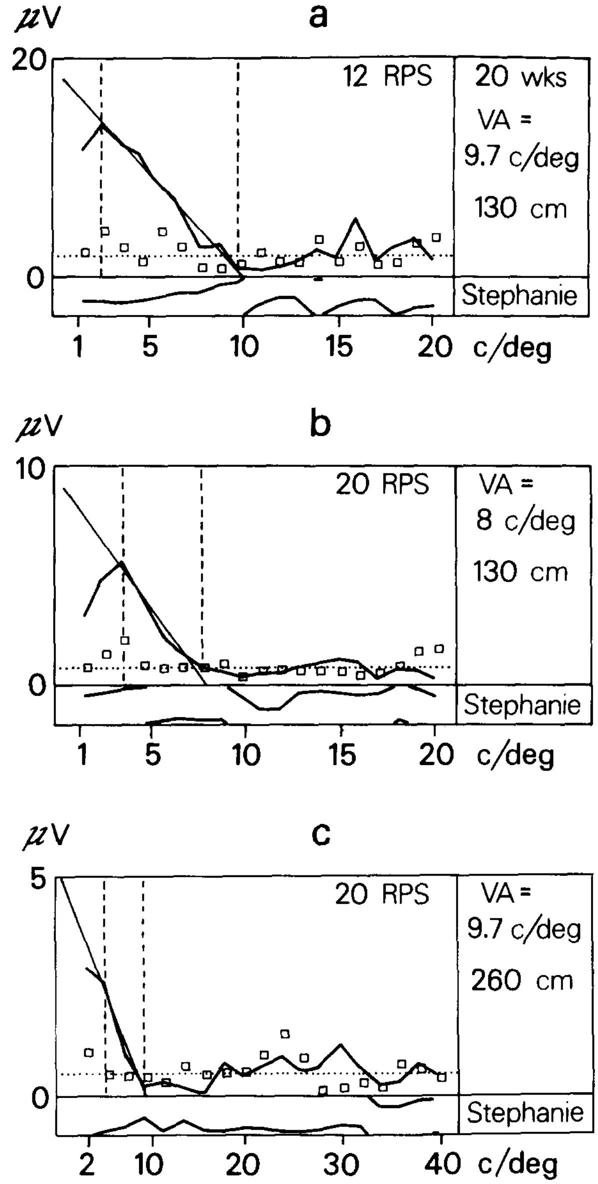

Fig. 1. Individual VEP amplitude versus spatial frequency functions at 12 and 20 rps. Solid lines plot the amplitude (upper segment of each panel) and phase (lower segment of each panel) at the stimulus alternation rate. Open square symbols plot the amplitude at 14 or 22 Hz for the 12 and 20 rps stimulation frequencies respectively. The form of the spatial tuning function is similar across temporal frequency (a and b) and viewing distance/field size (b and c). The intercept on the spatial frequency axis of the slanting regression line indicates the estimated acuity which is similar across a through c.

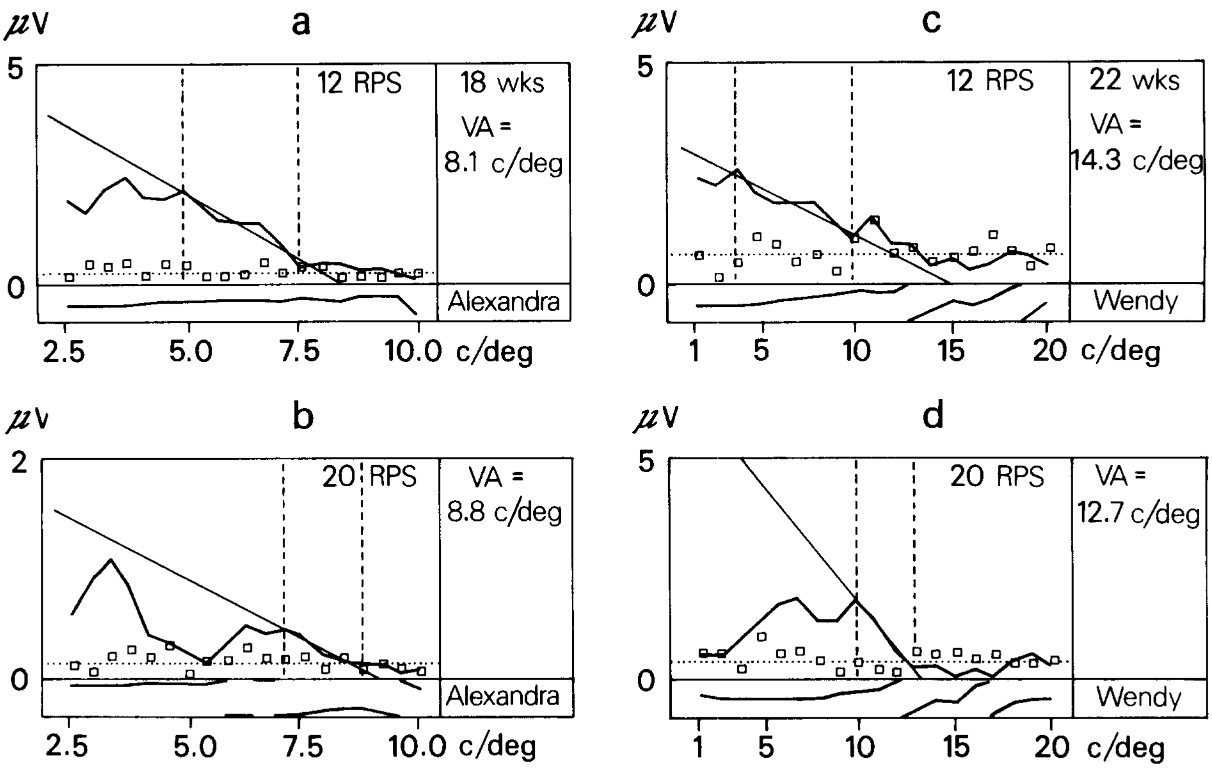

Fig. 2. Individual VEP amplitude versus spatial frequency functions for two infants showing similar acuity values but different spatial tunings with temporal frequency.

frequencies. VEP acuity, however, is quite similar for both infants at the two temporal frequencies. In a the spatial tuning function for Alexandra at 12 rps consists of a single broad spatial frequency peak, while at 20 rps (b) the spatial tuning function shows two peaks, one at 3.5 c/deg and the other 6.5 c/deg. Despite the differences in the form of the spatial tuning function measured at 12 and 20 rps, the acuities differ by only 0.12 octaves. Fig. 2c and d show data from a 22-week-old infant (Wendy), who showed a monotonically decreasing spatial tuning function at 12 rps and a function peaking at 6 and 10 c/deg when tested at 20 rps. Although the two spatial tuning functions are again quite different, especially at low spatial frequencies, the estimated acuities agree to within 0.17 octaves.

Fig. 3 shows one of the largest discrepancies in estimated acuity in the present data set. Fig. 3a shows the spatial tuning function measured at 20 rps using a spatial frequency sweep range of 1–20 c/deg. The function shows a single sharp peak at 3 c/deg and an estimated acuity of 6 c/deg. Fig. 3b shows data taken at 12 rps using a sweep range of 5–20 c/deg. The initial portion of the record shows a large response at 5 c/deg as in a; however, a second spatial frequency peak was recorded at approximately 7.5 c/deg. The acuities in this case differ by 0.87 octaves, which is still less than a factor of 2.

Variation of single 10 sec sweep estimates

The complete set of acuity estimates that could be used for the analysis of test/retest reliability is depicted in Fig. 4, with data taken at 12 rps shown in the upper panel and that taken at 20 rps in the lower panel. For each infant acuities from individual 10 sec sweeps, if available, are shown as the filled circles. The acuity estimates, if available, that we obtained for each temporal frequency by

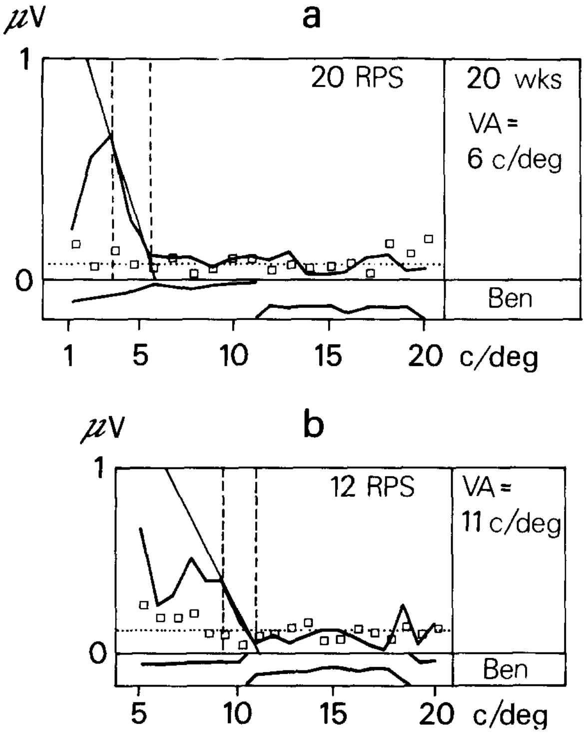

Fig. 3. Individual VEP amplitude versus spatial frequency functions showing one of the largest discrepancies in estimated acuity. The tuning function at 12 rps (b) shows a second spatial frequency peak not seen at 20 rps (a).

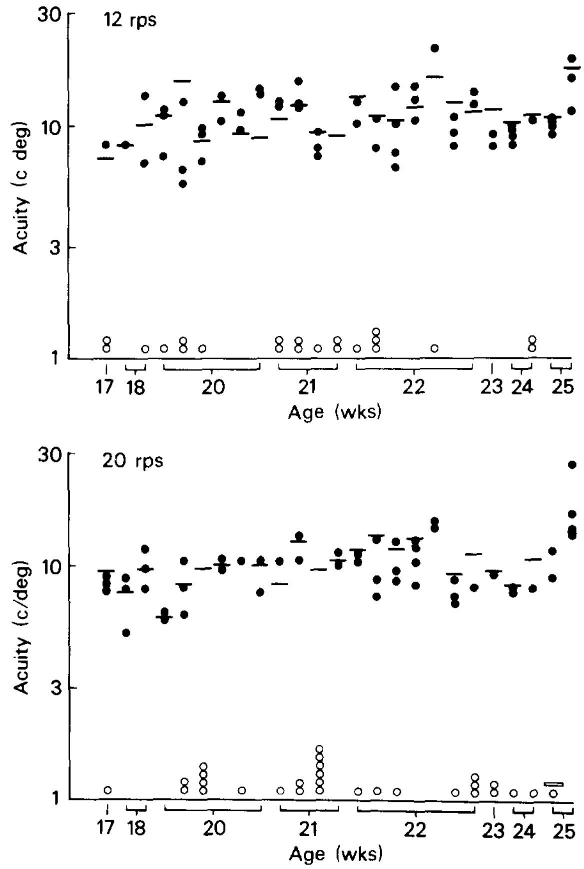

Fig. 4. Data used for reliability comparisons. Upper panel plots data taken at 12 rps, lower panel at 20 rps. Filled circles represent the acuities from individual 10 sec sweeps, if available. The bar symbol indicates the acuity, if available, obtained by vectorially averaging all sweeps taken under the same conditions. Open symbols along the abscissa indicate the number of individual sweeps for each infant which did not yield criterion responses.

vector averaging all available sweep records are shown as the bar. The open symbols plotted along the abscissa indicate for each infant the number of individual sweep runs (circles) or vector averages (bars) which did not produce a criterion response. Criterion responses were obtained on 75% of individual sweep trials at 12 rps and 65% at 20 rps. Only one vector average failed to yield a criterion response. The data are arranged in order of increasing age and all trials taken at 12 and 20 rps are shown.

One approach to the reliability of the spatial frequency sweep method is to determine the variation of the acuity measurements made on the basis of single 10 sec sweep runs. Twenty-one infants produced data sets for which two or more single sweeps with criterion signals were available at 12 rps. Eighteen such comparions were available at 20 rps. Four measures of reliability were calculated by one-way analyses of variance (ANOVA) with repeated measures, as summarized in Table I. Two analyses were performed at each temporal frequency: one for the infants with only two criterion single sweeps and one for infants with three or more criterion sweeps. The data were entered in the order taken within the session. When more than 3 single sweep estimates were available, the first 3 criterion estimates obtained were used.

The analysis of variance breaks the within-subject variability into a component due to the average difference in acuity between the repeated mea-

TABLE I

Sweep VEP reliability: single trials. Analyses of variance with repeated measures for acuities obtained in single sweep trials either 12 or 20 rps. N.S. = not significant at $P > 0.05$.

Frequency	Comparison	n	X (c/deg)	MSE (c/deg)	RMS (oct.)	% variance within subject
12 rps	Infants with 2 criterion records $F_{1,9} = 0.04$: N.S.	10	11.28	4.23	0.2416	37
	Infants with 3 criterion records $F_{2,20} = 0.1$: N.S.	11	10.02	6.58	0.3280	55
20 rps	Infants with 2 criterion records $F_{1,8} = 0.05$: N.S.	9	10.78	1.73	0.1662	6
	Infants with 3 criterion records $F_{2,16} = 0.17$: N.S.	9	10.04	7.95	0.3571	38

sures (order effect) and a residual error term. In the case of visual acuity measurement it is preferable to express the error in terms of octaves of spatial frequency. We also wished to convert the residual variance measure into a standard deviation so that we could establish confidence intervals. We thus first calculated the standard deviation as the square root of the mean square error variance term (RMS error) in cycles per degree. This error was then converted to octaves by referring the RMS error to the mean of the treatments (replications). These values are summarized in Table I.

At 12 rps the grand average acuity for all single sweeps was 10.55 c/deg (n = 59, S.D. = 2.92 c/deg) with the overall average acuity at 20 rps being 10.29 c/deg (n = 52, S.D. = 3.55 c/deg). The difference is not significant. None of the ANOVAs indicated a significant effect of testing order, the F ratios being all less than 0.17 as summarized in Table I. The RMS errors shown in Table I range from ± 0.17 to ± 0.36 octaves with the average being 0.27 octaves (0.28 octaves at 12 rps versus 0.26 octaves at 20 rps). Also tabulated is the mean squared error variance (MSE) in c/deg.

The within-subject variance ranges from 6 to 55% of the total variance across the 4 comparisons in Table I, the average being 34% of total variance. This small value indicates that differences in acuity between infants are substantially larger (66% of the variance) than the combined measurement error and order terms comprising the within-subject variance.

TABLE II

Analysis of variance for the reliability of the best acuity estimate at 12 rps compared to the best estimate at 20 rps.

Source of variation	SS	df	MSE	F	% of variance
Between subjects	464.42	2			86
Within subjects	77.7	25			14
Temporal frequency	10.95	1	10.95		3
Residual	66.75	24	2.78	3.94, N.S. *	11
Total	540.12				

* $F_{0.95}$ (1, 24) = 4.26

Reliability of the best acuity at each of two temporal frequencies

To determine the reliability of the highest acuity estimate available from either individual 10 sec sweeps or their average we compared acuities across 12 and 20 rps conditions.

The mean (n = 25) of the highest acuities at 12 rps was 12.43 c/deg (S.D. = 2.9 c/deg). At 20 rps the mean acuity was 11.49 c/deg (S.D. = 3.59 c/deg). The one-way analysis of variance for repeated measures summarized in Table II failed to show a significant effect of temporal frequency ($F_{1,24} = 3.94$, $P > 0.05$). Acuities at the two temporal frequencies were significantly correlated within individuals ($r = 0.76$, $P < 0.001$). The RMS error for the best acuity value is 0.19 octaves based on the mean squared error variance of 2.78 c/deg and an overall mean of 11.96 c/deg.

The analysis of variance indicates that 86% of the variance is accounted for by differences between subjects. The remaining 14% of the variance (within subjects) may be partioned into only 3% attributable to the temporal frequency difference, while 11% is due to residual measurement error.

It is possible that some of the between-subject variation in acuity was due to age differences in the sample, which span a range of 9 weeks. The contribution of age differences was determined by normalizing each infants best acuity scores against the mean growth function for 12 and 20 rps measured by Norcia and Tyler (1984). The percentage of between-subject variation was within 2% of the value obtained when age was not taken into account. This is not surprising given the distribution of ages in the samples which were rather tightly clustered around 21–22 weeks and also given the fact that VEP acuity is developing slowly over the 15–25 week age range (Pirchio et al. 1978; Sokol 1978; Norcia and Tyler 1984).

Invariance of best acuity with SNR

Tyler et al. (1979) suggested that the linear extrapolation of VEP acuity should be independent of signal amplitude (SNR). Scaling the amplitude of the response, while affecting the SNR, should not affect the *shape* of the tuning function or the zero amplitude intercept. Any bias in our technique should be most apparent for the best acuity measure since it is the extreme value in the distribution of individual acuities. We find, however, that best acuity and SNR are uncorrelated in our sample at both 12 and 20 rps ($r_{12} = -0.37$; $P < 0.05$, $r_{20} = 0.07$; $P < 0.05$, each two-tailed).

Discussion

The results of the present analysis indicate that VEP acuities can be estimated in infants with a high degree of precision using the swept spatial frequency technique. From Table I, the standard deviation for single 10 sec trials averages 0.27 octaves across the two temporal frequency conditions. Repeated measures based on the highest acuity at each temporal frequency have a standard deviation of 0.19 octaves. The higher reliability and the reduction of within-subject variance (Tables I and II) suggests that using the highest estimate is not an unreasonable procedure for assigning acuities, especially since it has the additional advantage of yielding a higher limit for infant grating resolution. This limit should be regarded as a lower bound on infant performance and not as a clearly defined maximum. Overall, both error measures are quite similar and are small relative to the total range of acuities in the sample, which span a range of about 2 octaves. The same level of individual variation remains after accounting for (small) age differences in the sample. Thus there are substantial and reliable individual differences in VEP acuity estimated by our procedures.

The temporal frequency of the grating alternation accounts for only 3% of the total variance and 14% of the within-subject variation (Table II), suggesting that the possible artifact of differential temporal tuning pointed out by Regan (1978) is small on average over the 12–20 rps range. The major difficulty in estimating acuity from the VEP amplitude versus spatial frequency function lies in the frequent occurrence of an amplitude peak at more than one spatial frequency when steady-state grating reversal is used, and in that the form of the function depends on temporal frequency (Tyler et al. 1978, 1979; Apkarian et al. 1981; and Figs. 2 and 3 above). More than one peak in the VEP amplitude versus spatial frequency function has also been reported for transient patterned flashes (Harter et al. 1977) and checkerboard appearance targets (Spekreijse 1978). If the spatial tuning function is measured accurately, the final peak in the spatial frequency function can be determined and the acuity extrapolation may then be based on its falling slope. Acuities measured in this fashion at 12 and 20 rps are highly correlated in our sample although the actual form of the spatial tuning function at the two temporal frequencies may have been quite different.

Comparison with other techniques for measuring infant acuity

The cross-sectional mean acuity values obtained using the sweep method are comparable to those obtained by other investigators using different VEP methods (Norcia and Tyler 1985). The VEP studies most comparable to ours are the studies of Pirchio et al. (1978) and Sokol (1978) who have also tested groups of infants in the 17–25 week range using pattern reversal rates comparable to those of the present study. Those studies presented a limited number of spatial frequencies one at a time and acuity was estimated as a regression to zero amplitude on the resulting VEP amplitude versus check-size or spatial frequency function. While the acuity values obtained using patterns presented one at a time are comparable to the present results, it can be seen in Sokol's Fig. 3 that cross-sectional variability increases with age and increasing acuity and has a standard deviation of as much as 2 octaves in the 17–25 week range. Some of this variability may be accounted for by the fact that Sokol's extrapolation was based on linear check-size which corresponds to the use of a *hyperbolic* spatial frequency axis. With the hyperbolic axis, small deviations in the intercept due to measurement error result in large fluctuations in the estimated acuity. Using the linear spatial-frequency sweep method we have found (Norcia and Tyler 1984) that cross-sectional variability is more nearly constant over the first year with an average standard deviation of ± 0.44 octaves.

Acuities obtained with a variety of VEP techniques, including our own are substantially higher than those obtained with behavioral techniques (reviewed by Mayer and Dobson 1982), although cross-sectional variability is roughly the same.

Sources of individual variation

At present it is not clear what may be the source(s) of individual differences in our cross-sectional sample. It remains to be seen whether these differences constitute genuine individual differences in the development of visual capacity or whether they are attributable to methodological factors related to VEP recording, to uncorrected refractive or accommodative errors, or to uncontrolled infant state changes. Large individual differences in a normal population, whatever their source, make it more difficult to discriminate small pathological acuity losses from the range of normal variation.

In general, the main methodological difficulties with VEP recording lie in individual differences in cortical geometry which may affect measurements made at the scalp and uncontrolled state changes over the duration of the recording session. Each of these sources is somewhat difficult to quantify and thus it is hard to assess their contribution to the overall variability seen in infant populations.

Somewhat more is known about the likely range of infant refractive and accommodative errors. Depending on pupil size, 1–2 D of ametropia not compensated by accommodation or 1–2 D of accommodative error could affect retinal contrast over the 6–24 c/deg acuity range in our sample (Hopkins 1955; Campbell and Green 1965). A high degree of accommodative accuracy and an emmetropic refraction with respect to the viewing distance would have to have been present for the few infants with acuities over 20 c/deg. It is possible that the remaining infants did not accommodate with the same accuracy or had residual refractive errors. However, the available data on infant accommodation (reviewed by Banks 1980) make it unlikely that most 17–25-week-old infants' accommodative error would be as large as 1–2 D at the 1.3 or 2.6 m test distances used in the present study. Since the present study concerns reliability, we did not explore the effects of viewing distance beyond the example shown in Fig. 1. Given the magnitude of the measurement error associated with the present data, accommodative *variability* within infants cannot have been at all large. It would nevertheless be desirable in the future to measure both refractive and accommodative state to ensure that refractive variability does not contaminate the measurement of individual differences in neural acuity development.

Regardless of the source of variability between infants, the within-session repeatability of sweep VEP acuity measurement is good. The sweep technique is also a robust method for measuring cortical resolution limits, with 65–75% of individual sweep records yielding a criterion response. The RMS measurement error of ±0.19 octaves is comparable to the 0.33 octave resolution of the smallest division on a Snellen chart. Thus the normal VEP acuity range can be restricted with confidence to a relatively narrow band.

Résumé

Mesures de l'acuité du potentiel évoqué visuel chez le nourrisson: analyse des différences individuelles et des erreurs de mesure

La fiabilité des mesures d'acuité par le potentiel évoqué visuel (PEV) a été déterminée en estimant l'acuité à l'aide de réseaux sinusoïdaux de luminance, modulés en opposition de phase à raison de 12 ou de 20 inversions/sec. La fréquence spatiale des réseaux était amenée au-delà de la limite d'acuité, celle-ci étant estimée sur la base du dernier pic d'amplitude du PEV en fonction de la fréquence spatiale. Vingt-cinq nouveau-nés âgés de 17 à 25 semaines ont été étudiés.

Avec des balayages uniques de 10 sec on a obtenu des réponses au critère dans 65 à 75% des essais. La fiabilité des acuités mesurées à partir de balayages uniques de 10 sec était de ±0,54 octaves à 95% de limite de confiance pour les conditions d'enregistrement avec 12 et 20 inversions/sec (erreur de la moyenne des carrés ±0,27 octaves). La meilleure acuité atteinte par chaque nouveau-né, soit sur un balayage unique, soit sur le moyennage vectoriel, était fiable à ±0,38 octaves avec une confiance de 95% (erreur de la moyenne des carrés: ±0,19 octaves) comparée aux 2 octaves à l'intérieur desquels se situent les acuités de chaque individu. Si, chez des nourrissons, on considère l'acuité mesurée sur des balayages de PEV, la plus grande partie de la variabilité calculée sur des échantillons transversaux, est donc attribuable à des différences individuelles stables plutôt qu'à des erreurs de mesures. Lors de tests sur des nouveau-nés donnés, notre analyse indique que le choix de la fréquence temporelle ne rend compte que de 14% de la variation de l'acuité estimée pour un sujet donné.

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