


Behavioral measurement of background adaptation in infants. RONALD M. HANSEN AND ANNE B. FULTON.

Thresholds for detecting blue test flashes in the dark-adapted condition and on steady red background fields were measured in 2- to 18-week-old human infants by a two-alternative forced-choice preferential looking method. The results show that dark-adapted sensitivity increases and background adaptation develops during the early postnatal weeks. Thus, the retinal mechanisms that underlie (1) detection of brief flashes and (2) neural processing in background adaptation appear to mature postnatally. (INVEST OPHTHALMOL VIS SCI 21:625-629, 1981.)

Recently Powers et al. showed that the scotopic sensitivity of human infants increased postnatally. This demonstration, along with the finding that background adaptation in infant rats continued to develop after distal retinal morphogenesis was nearly complete (as in neonatal humans), raised the possibility that scotopic background adaptation also developed postnatally in human infants. To find out, we have modified the two-alternative forced-choice preferential looking method to measure the effects of steady backgrounds on thresholds for detecting flashes of light. Preliminary results indicate that background adaptation in very young infants is different from that of adults but matures during the early postnatal weeks.

Methods. Three 500 W tungsten sources projected test stimuli and backgrounds onto a 107 by 107 cm rear projection screen in a dark room. One source produced a diffusely illuminated 110° diameter circular background field centered on the screen. The other beams, one on the right and one on the left, produced 10° diameter test spots located 20° to the right and left of the center of the screen. The sources, lenses, and stops were mounted in light-tight boxes to prevent stray light from reaching the screen. Test stimuli were 1 sec duration blue (Ilford 621) flashes; the steady background beam was red (Wratten 29). Both background and test-spot intensity were controlled by neutral density filters. Luminance measurements were made with a calibrated photodiode (UDT; Model 11A). The unattenuated test beams had a luminance of 2.11 log mJ, and the background had a luminance of 2.86 log mJ.

After dark adaptation for 30 min, the infant was held 50 cm in front of the dark rear projection screen by an adult (the holder). A second adult (the experimenter, positioned behind the screen) attracted the infant’s gaze to the center of the screen by flickering a dim yellow flashlight (30 min arc diameter). A third adult (the observer) watched the child with an infrared viewer (FJW Industries; Model 3420). The observer, hidden in black curtains adjacent to the screen, could view the infant from above, below, or to the right or left of the screen. When the observer reported that the infant was alert and looking at the center of the screen, the experimenter extinguished the fixation light and presented a test spot. The observer faced the infant and could not see the stimuli. Based on the infant’s looking behavior, the observer reported stimulus location on every trial. After each response, the experimenter told the observer whether the judgment was correct. We assume that the infant looked toward the flash if it was detected. Stimuli were repeated, when necessary, to allow the observer to make a decision.

Initially the infant was shown stimuli that were 2 to 3 log units above the adult dark-adapted threshold. These stimuli were detected readily and enabled the observer to become familiar with the infant’s looking behavior. If the observer correctly reported spot location on the first five trials (100% correct), test-spot intensity was reduced by 0.6 log units. * Target intensity was reduced further until the observer made an error. Then, ten trials were run at that and each succeeding test-flash intensity. Stimulus intensity was reduced in 0.3 log unit steps.

*The probability of guessing stimulus location correctly is 0.5 in a two-alternative forced-choice task. Assuming that each trial was an independent event, the probability that the observer correctly guessed test-spot location on five trials in a row was 0.031 (from the binomial probability distribution with n = 5, r = 5, and p = 0.5). Thus it was unlikely that the observer’s percent correct was due to guessing, but rather reflected the infant’s visual performance.
Fig. 1. Results of psychophysical measurement of retinal adaptation to red backgrounds in a 2-week-old infant. A, Psychometric functions from six adaptation conditions. Observer’s percent correct is plotted as a function of log test-flash intensity (in quanta sec"1 cm"2 at 502 nm incident at the cornea) in the no-background (dark-adapted) condition and in each of five background conditions producing retinal illuminations of -3.3 to +0.7 log scotopic trolands. Arrows indicate interpolated thresholds for 75% correct responses. B, Results of this experiment were summarized by plotting log threshold test-flash intensity as a function of log background intensity. Open square (on the axis), Threshold in the dark-adapted (no-background) condition.

until performance fell to chance (50% correct). With adult subjects, this order and rate of stimulus presentation did not alter the state of adaptation. We assume that this was also the case with infants. Occasionally, when test stimuli were near threshold, the experimenter added brighter test flashes to keep the infant alert and interested.

A dim red background of about -3 log scotopic trolands was added and a second psychometric function was measured. The steady background was then increased by 1.0 log unit and another function was measured. This process was continued up to a background of about +2 log scotopic trolands. The 120 to 150 trials from which Weber-Fechner functions were derived were completed in 1 day. Total test time for infants was about 2 hr; adults completed testing in less than an hour.

One infant was tested at age 2 weeks, one at 4...
Legend Background Intensity (Scotopic Trolands)

Fig. 2. Increment threshold curves at various ages. Log threshold test-flash intensity is plotted as a function of log background intensity for infants tested at age 2, 4, 8, 12, and 18 weeks. The final graph presents the averaged results from five normal adult subjects tested with the same apparatus and procedure; error bars show ±1 S.D. For comparison, the average adult curve is plotted as a dashed line on each of the other graphs.

Weeks, one at 8 weeks, one at 12 weeks, and one at 18 weeks. All infants tested were born at term, and ophthalmic examination revealed no abnormalities. Increment threshold curves were also obtained from five adults using the same apparatus and order of stimulus presentation; adults named the position of the stimuli, right or left. For all experiments, both adult and infant subjects' pupils were fixed and dilated with Cyclogyl 1% or Mydriacyl 1%. Pupillary diameter, measured at the end of each test session, was used to calculate retinal illumination.

Results. Psychometric functions from an infant tested at age two weeks are presented in Fig. 1, A; each function summarizes data from a single adaptation condition. Observer's percent correct detection varied from 100% correct for bright stimuli that were well above threshold to chance (50% correct) for dim stimuli. Threshold was defined as the stimulus intensity that was reported correctly 75% of the time. Thresholds for all subjects were determined graphically from psychometric functions such as those in Fig. 1, A. Thresholds of the 2-week-old infant in each adaptation condition are plotted as a function of log background intensity in Fig. 1, B. The results from the 2-week-old and other infants are summarized in Fig. 2. For comparison, thresholds obtained from five adult subjects are also shown in Fig. 2.

The dark-adapted threshold for the 2-week-old infant was equivalent to 6.3 log quanta sec⁻¹ cm⁻² at 502 nm incident on the cornea; this is about 1.4 log units above the adult dark-adapted threshold. The sensitivity of dark-adapted infants increased with age (Fig. 2). At age 18 weeks, dark-adapted sensi-

*Retinal illuminance at threshold was calculated with the relation

\[ n(\lambda) = I_T \times (A_p / A_r) \]

where \( n(\lambda) \) is the number of quanta sec⁻¹ cm⁻² (502 nm) at the retina, \( I_T \) is the threshold test flash in quanta sec⁻¹ cm⁻² incident on the cornea, \( A_r \) is the effective transmittance for adults or infants, \( A_p \) is the pupil area in cm², and \( A_r \) is the retinal area of the stimulus in cm². \( I_T (502 \text{ nm}) \) was calculated from the output of the source measured with a calibrated photodiode in the position of the subject's eye; the energy distribution of the source and relative sensitivity of the diode were taken into account. Scotopic matches for the blue filter were set by adult observers and the attenuation caused by the filter determined assuming (1) the output of the source was constant across the wavelengths passed by the blue filter and (2) all wavelengths were attenuated uniformly. Age-related changes in eye size were taken into account. At age 2 weeks, \( n(\lambda) = 6.86 \log \text{quanta sec}^{-1} \text{cm}^{-2} \) at 6.84 at 4 weeks, 6.42 at 5 weeks, 6.13 at 12 weeks, 5.67 at 18 weeks, and 5.09 for the average adult threshold.
sitivity equaled that of adults. The average adult dark-adapted threshold (4.9 log quanta sec\(^{-1}\) cm\(^{-2}\) at 502 nm incident at the cornea) agreed well with thresholds reported by Denton and Pirenne\(^6\) for subjects viewing large (45° diameter), long duration (5 sec) stimuli binocularly.

The eigengrau (intersection of asymptotes to the horizontal and rising limbs of the Weber-Fechner function\(^7\)) for adults was +1.7 log scotopic trolands (S.D. = 0.2 log scotopic trolands; n = 5); this is somewhat higher than the value found in the best of psychophysical test conditions.\(^5\) Although some of the curves are difficult to interpret, the eigengrau for most infant subjects was approximately equal to that of adults; no systematic changes with increasing postnatal age were seen.

The slope of the linear portion of the adult curve (Fig. 2) was +0.96 (S.D. = 0.04; n = 5) and is similar to that reported by others.\(^7\) The steepest portion of the incremental threshold curve for the 2-week-old infant was +0.6. Between ages 2 and 18 weeks the slope increased, and by age 18 weeks it was +0.9.

Discussion. The progressive decrease in the dark-adapted threshold and increase in the slope of the increment threshold curves suggests that adaptive processes develop in the early postnatal weeks. These age-related changes might be attributed to increasing attentiveness to dim stimuli as the infants became older. However, throughout the test sessions for infants of all ages, the observer's score remained at or close to 100% correct for bright stimuli and decreased in a regular fashion to 50% as the stimuli were made dimmer (Fig. 1, A). Also, direct surveillance by the observer ensured that the infant was indeed alert and in good position whenever a trial was initiated. Thus attentional factors are unlikely to have influenced the functions obtained.

The absolute sensitivity of our dark-adapted 4- and 12-week-old infants was in reasonable agreement with those of 1- and 3-month-old infants studied by Powers et al.\(^1\) In that study, the spectral sensitivity indicated that the responses were rod mediated; thus the dark-adapted thresholds of our infants must also be rod mediated. One would be suspicious of cone intrusion in the various background conditions, partly because anatomical maturation of peripheral cones precedes that of rods\(^3\) and in adults rod-cone interactions occur with blue test flashes in the presence of red backgrounds.\(^10\) However, responses are rod mediated if, as in the present experiment, background fields are large and peripheral retina is tested.\(^5\) In those adult experiments\(^5, 11\) in which it was possible to exploit fully spectral and directional sensitivities, the scotopic increment threshold curves obtained were similar to those of our adults.

Direct observation of the infants suggests that they also used peripheral retina to detect the test flashes; the infants appeared to fixate the center of the screen at the start of each trial, but after presentation of the 20° eccentric test flash, typically turned head or eyes, or both, toward the flash on the right or the left. Thus we suspect that the infants' increment thresholds also represent scotopic function, although the contribution of peripheral cones to visual sensitivity and the role of rod-cone interactions in the early postnatal period cannot yet be specified.

The increase in slope of the linear portion of the incremental threshold curves that occurs between age 2 and 18 weeks in human infants is similar to that of young rats between ages 18 and 40 days.\(^2\) The scotopic b-wave that was used to assess sensitivity in the rats depends mainly on distal retinal activity; the increasing slope of the incremental b-wave sensitivity curves is thought to reflect maturation of the functional organization of the rat retina.\(^2\) The changes in the slope of the human infants' Weber-Fechner functions\(^5\) may also be caused by postnatal development of retinal function. Adaptive mechanisms in infants can be tested further in experiments that vary temporal, spatial, and spectral properties of stimuli; retinal organization of adults is such that these parameters influence the shape of Weber-Fechner functions.\(^5\) Meanwhile, the procedure as described allows measurement of the dark-adapted threshold and steady-state retinal adaptation in pediatric patients who cannot have retinal function evaluated by other psychophysical methods.\(^12\)

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REFERENCES


