Infant Behavior & Development 36 (2013) 329–343

Contents lists available at SciVerse ScienceDirect

Infant Behavior and Development

# The onset of sensitivity to horizontal disparity in infancy: A short-term longitudinal study

Michael Kavšek*

*University of Bonn, Department of Psychology, Unit of Developmental and Educational Psychology, Kaiser-Karl-Ring 9, 53111 Bonn, Germany*

ARTICLE INFO

*Article history:*
Received 4 April 2012
Received in revised form
15 November 2012
Accepted 21 February 2013
Available online 1 April 2013

*Keywords:*
Infant vision
Perceptual development
Stereoscopic vision
Horizontal disparity

ABSTRACT

In this short-term longitudinal study, infants were examined for their natural preference of a square defined by crossed horizontal disparity (either 1° or 0.5°) over a square defined by a vertical disparity (either 1° or 0.5°). The square targets were embedded in a dynamic random dot stereogram. The stimuli were presented on an autostereoscopic monitor equipped with a face-tracking device. The infants were tested weekly between 6 and 16 weeks of age. Four experiments were conducted. In two experiments, the infants were examined with the forced-choice preferential looking (FPL) method for their ability to perceive either 1° or 0.5° horizontal disparity. In the remaining two experiments, the classical natural preference (CNP) method (measurement of looking times) was applied. According to the results of the FPL experiments, mean relative preference for the horizontal disparity square became significant at 8 weeks of age. The CNP data indicated an onset of stereopsis at 12–15 weeks. The mean relative preferences for horizontal disparity indicated by the CNP method were smaller than those found in the FPL experiments. Thus, the FPL method was more sensitive than the CNP method in the measurement of infant responsiveness to crossed horizontal disparity.



Our visual system extracts depth from pictorial, kinematic, and binocular cues. Most studies on infant depth perception have dealt with responsiveness to pictorial and kinematic cues to depth (e.g., Kellman & Arterberry, 2006). The research on stereopsis in infants has concentrated on sensitivity to binocular disparity. Two paradigms, measurement of visual evoked potentials (VEP) and measurement of behavioral responses, have been applied in earlier studies. These studies suggest that responsiveness to horizontal disparity arises at approximately 3–5 months of age (for summaries, see Birch, 1993; Held, 1991). The present preferential-looking study investigated the ability to extract horizontal disparity in infants 6–16 weeks of age.

Birch and Petrig (1996), Petrig, Julesz, Kropfl, Baumgartner, and Anliker (1981), and Skarf, Eizenman, Katz, Bachynski, and Klein (1993) measured VEP responses to dynamic random dot stereograms displaying regions which continuously jumped from above (crossed disparity) to below (uncrossed disparity) or into a reference surface. According to the results of these investigations, infants younger than approximately 2 months of age generally failed to produce VEP signals to the stereograms. From that age onwards, however, the number of infants demonstrating VEP stereopsis increased steadily. Clear VEPs were found for most infants over 3 months of age.

Behavioral studies observed infants' looking at stimuli containing horizontal disparity information. Most studies have applied the *forced-choice preferential looking (FPL) technique* (e.g. Teller, 1979, 1997). In the two-alternative version of the FPL

* Tel.: +49 228 734360; fax: +49 228 734639.
*E-mail address:* kavsek@uni-bonn.de


http://dx.doi.org/10.1016/j.infbeh.2013.02.002

technique, two stimulus targets, one containing horizontal disparity and one lacking horizontal disparity, are simultaneously shown to the infant over numerous trials. A trial is ended when the observer has judged which stimulus the infant has attended to. Since a trial lasts a few seconds only, a large number of trials can be conducted. From the observer's judgment, a relative preference score is computed. The relative preference score indicates how often the infant preferred the stimulus with horizontal disparity over the stimulus without horizontal disparity.

Using the FPL paradigm, Held, Birch, and Gwiazda (1980) tested infants' perception of line stereograms. In the critical target stimulus, some of the lines appeared either in front of (crossed disparity) or behind (uncrossed disparity) a reference surface. The comparison stimulus contained lines with zero disparity. Held et al. (1980) found a mean age of 16 weeks for the onset of stereopsis, indicated by a preference for the lines containing horizontal disparity. However, the results were different for uncrossed versus crossed disparities. The average age at first preference for a 58 min crossed disparity was 12 weeks, the average age at first preference for a 58 min uncrossed disparity was 17 weeks (see also Birch, 1985; Birch, Gwiazda, & Held, 1982; Birch, Shimojo, & Held, 1985). Gwiazda, Bauer, and Held (1989) established that female infants exhibit an earlier onset of sensitivity to crossed horizontal disparity than male infants. Average age of onset of responsiveness to 32 min horizontal disparity was 9.1 weeks for females and 12.1 weeks for males. Held, Thorn, Gwiazda, and Bauer (1996) delineate that the data collected by Held et al. (1980) and by Birch et al. (1982) revealed sex differences as well.

In line stereograms, the relative shift of the lines with horizontal disparity in the two half-images can be detected by alternate eye closure. This monocular cue is eliminated in dynamic random dot stereograms (RDS), the random dots in which are continuously replaced at a high rate. The stereoscopic form is generated by a relative horizontal shift of a region within the random dot elements in the half-images. This relative horizontal displacement is held constant across the replacements of the random dots.

An early study on infants' visual behavior toward dynamic RDS has been conducted by Fox, Aslin, Shea, and Dumais (1980; see also Shea, Fox, Aslin, and Dumais, 1980). These authors took advantage of dynamic RDS to camouflage a motion of the horizontal disparity region (e.g., Fox, 1981). More specifically, they repeatedly presented their participants with a dynamic RDS, the critical stereoscopic contour in which was moved laterally, to either the left or the right. In each trial, an observer judged the direction of the movement by following the infant's visual behavior. Accordance between direction of stimulus motion and direction of judged motion significantly exceeded chance level in infants 3.5, but not in infants 2.5 months of age (Experiment 1). A two-alternative FPL study with dynamic RDS has been conducted by Birch and Petrig (1996). The critical target in this study consisted of alternate crossed and uncrossed horizontal stripes. The stripes continuously reversed in depth. This dynamic stimulus was presented on either the left or right side and was paired with a dynamic RDS lacking depth effect, placed on the other side. Number of infants who displayed a preference for the critical target in more than 75% of the trials increased steadily from 3 to 8 months. At the age of 3–4 months, about 60% of the infants gave evidence of stereopsis.

Held et al. (1980) ran a number of control conditions to test whether the infants in the main condition might have responded to disparity per se instead of responding to *horizontal* disparity. In one of the control conditions, Held et al. (1980) presented a disparity stimulus, the critical target in which was specified by a vertical disparity. Held et al. (1980) observed no preference for this vertical disparity stimulus. According to this finding, instead of responding to disparity as such, the infants in the main condition were obviously sensitive to horizontal disparity.

In the line stereogram studies, onset of stereopsis was defined as the earliest age at which an infant displayed a preference for horizontal disparity over zero disparity in more than 75–80% of the FPL trials. From the individual onset scores, average age of onset of stereopsis was determined. In contrast, in the dynamic RDS studies conducted by Fox et al. (1980) and Shea et al. (1980), average onset of stereopsis was defined as the earliest age at which the mean preference for horizontal disparity of an infant sample significantly exceeded chance probability (.50). Despite these differences in data analysis, the line stereogram and dynamic RDS studies uniformly reported a mean onset of stereopsis after 3 months (e.g., Held, 1991).

Using static random texture stereograms, Brown, Lindsey, Satgunam, and Miracle (2007) presented infants with a square region defined by a crossed horizontal disparity of 35 min versus a square region defined by a vertical disparity of the same amount. Consistent with the findings from line stereogram and dynamic RDS studies, Brown et al. observed that the infant participants' ability to detect the horizontal disparity target was near chance performance at 12 and 13 weeks of age and exceeded the chance level from 14 weeks onwards. In another FPL study with static RDS, however, Brown and Miracle (2003) found that the median preferences for a rectangular with 56 min horizontal disparity over a zero disparity region exceeded .75 from 8.6 weeks of age onwards. Age range of the infants was 7–12 weeks. The infants participated in 2 up to 6 test sessions. Wattam-Bell (2003) tested infants between 5–6 and 23–25 weeks of age with static RDS depicting alternate horizontal stripes of crossed and uncrossed disparity versus randomly distributed crossed and uncrossed disparities. Mean preference for the critical disparity target exceeded 60% at 9–10 weeks of age: From that age onwards, the infants preferred the critical target over the target with randomly distributed disparities in more than 60% of the trials. A >75% mean performance was attained between 13–14 and 17–18 weeks of age. Unfortunately, it was not examined whether the mean performance for the critical target found at 9–10 weeks deviated statistically significant from chance performance.

The present study pursued several goals. One goal was to follow the onset of sensitivity to horizontal disparity in the first months of life. The infants were tested weekly between 6 and 16 weeks of age for their ability to detect horizontal disparity in a dynamic random dot display. Dynamic instead of static RDS were employed because the relative shift of the region defined by horizontal disparity can be detected by alternate monocular views, not only in line stereograms but also in static RDS (Birch, 1993). The 6–16 weeks age range was selected as it covers the ages at which prior studies found onset of stereopsis.