Bulletin of the Psychonomic Society
1990, 28 (4), 300-301

Development of the spiral aftereffect

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A motion aftereffect is the apparent motion of a stationary object that is seen after looking at a continuously moving object for a period of time. The aftereffect is of short duration and opposite in direction to the original motion. Duration of the spiral aftereffect was measured for children between 7 and 14 years of age after inspection durations between 30 and 180 sec. Aftereffect duration increased with inspection duration at a rate that was independent of age, but average duration increased with age. These differences in the development of properties of the motion aftereffect suggest that it may be an index of the neuronal arborization component of brain growth.

The term *motion aftereffect* refers to the apparent motion of a stationary object that one sees after looking at a continuously moving object for a period of time. The aftereffect is opposite in direction to the original motion and decays rapidly, rarely lasting more than half a minute or so. The duration of the aftereffect increases with increases in the length of time of the original observation (Hershenson, 1988, 1989; Taylor, 1963). We have found differences in the developmental properties of the spiral aftereffect which suggest that aftereffect duration may be an index of the neuronal arborization component of brain growth (Epstein, 1986).

Qualitative and quantitative differences in the properties of motion aftereffects have been used as evidence that the visual system contains sensory channels that are specifically tuned to different aspects of proximal stimulation (Regan, 1986). Structures have been identified that detect rectilinear motion, motion in opposite directions in a single meridian (size change), expansion or contraction in more than one meridian (motion in depth), and rotational motion (Beverley & Regan, 1979a, 1979b; Cavanagh & Favreau, 1980; Regan, 1986; Regan & Beverley, 1978, 1985). Because the sensory channels that produce specific motion aftereffects are thought to be building blocks of motion perception (Regan, 1986), these components of the visual system should be operative soon after birth. They certainly should be mature by the time the infant is able to locomote. Nevertheless, there are reports that the duration of the motion aftereffect changes markedly over the course of development (Andersson & Ruuth, 1971; Andersson, Ruuth, & Ageberg, 1977; Harding, Glassman, & Helz, 1957; Harris, 1983), but no consistent trends have emerged.

To clarify how the duration of the motion aftereffect changes with age, we studied the spiral aftereffect in 16 children between 7 and 14 years old. The subjects were 9 males and 7 females who had normal or corrected-to-normal vision. The stimulus was a three-turn (780° of arc), left-throw Archimedes spiral. The arm was 1.5 cm wide and was printed in black on a white disk 20 cm in diameter. In the test situation, the children sat approximately 2 m from the stimulus, so that the spiral subtended approximately 5.7° of visual angle. The spiral rotated clockwise at approximately 80 rpm. There were six inspection durations: 30, 60, 90, 120, 150, and 180 sec, presented twice for each subject. The order of presentation for the first series was randomized for each subject, and the second presentation followed the reverse order. Approximately 1 min elapsed between trials.

The experimenter explained the procedure according to the demands of the situation. In general, the children were told that the spiral would turn, and that, when it stopped turning, they might see it move in the opposite direction. They were told to say "stop" when it looked as if the spiral was not moving at all. They were also told at the beginning of a trial to look at the center of the spiral and to keep looking at the center until the spiral was completely still. The subjects were given two 30-sec practice trials prior to the first series.

The results can be seen in Figure 1, which shows the aftereffect duration as a function of inspection duration plotted on log-log axes for each child. An analysis of variance was computed on reciprocal transforms of aftereffect durations for each replication within subjects × inspection duration. The main effects of inspection duration [$F(5,80) = 88.14$, $p < .001$] and subjects [$F(16,16) = 16.00$, $p < .001$] were significant, but the interaction was not [$F(75,80) = 1.56$, $p > .05$]. The plot contains the lines of best fit computed for each subject from the geometric means at each inspection duration (mean $r^2 = .84 \pm .12$).[1] The respective ages are adjacent to the lines.

The duration of the spiral aftereffect clearly increased as a function of inspection duration. Moreover, the rates of increase were remarkably similar. The mean slope, which was $.33 \pm .03$, did not vary systematically with age ($r = .26$, $p > .05$). The differences among the subjects were manifested in the intercepts, which did increase with age ($r = .82$, $p < .001$). This pattern can be seen

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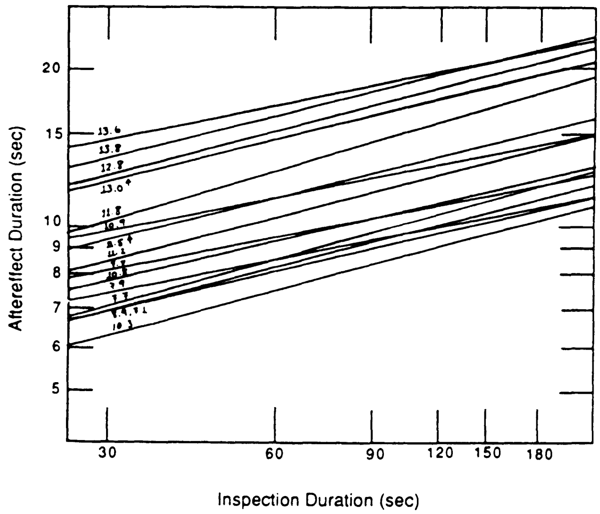

Figure 1. Duration of the spiral aftereffect as a function of inspection duration on log-log axes for each subject. The respective ages of the subjects are adjacent to the lines.

in Figure 1: the lines for the younger subjects tend to be lower than the lines for the older subjects.

In summary, the duration of the spiral aftereffect increased at a fixed rate with inspection duration regardless of age—a rate that is similar to that found in adults (Hershenson, 1988, 1989; Taylor, 1963). However, the absolute strength of the aftereffect, as indexed by its duration, did increase with age. Two possible explanations spring immediately to mind. The first suggests that the age changes reflect changes in criterion—the degree of perceived motion that the subject is willing to call "no motion." The motion aftereffect has a small but long-lasting component that can be observed for many days (Hershenson, 1985; Masland, 1969). Clearly, the judgment is subjective, and one could argue that the criterion for the judgment changes with age because it is related to the cognitive development of the child. The argument against this explanation comes from the one consistent finding in motion aftereffect studies with children: When cognitive ability is measured, the age changes are not related systematically to measurements of the duration of the spiral aftereffect (Andersson & Ruuth, 1971; Andersson et al., 1977; Harding et al., 1957; Harris, 1983). There does appear to be a relationship between IQ score and duration of the spiral aftereffect (Bhattacharyya & Chattopadhyay, 1981), but IQ does not increase with age.

The second explanation relates the changes to well-established brain growth patterns (Epstein, 1986). Clearly the brain is growing during the age range of the subjects tested. If the spiral aftereffect is related to structures in the visual system that are formed early, this brain organization may be manifested in the relatively stable rate of increase of duration with inspection duration. The increase in overall duration with age could reflect the increase in arborization of neurons.

This hypothesis is supported when the data are analyzed as biennial increments. For the younger subjects (7-10 years), there was relatively little increase in duration, whereas for the older subjects (11-13 years), the relative increase was large. It must be granted that these data are based on too few cases to be more than suggestive, yet it is a noteworthy coincidence that the large duration increments occurred during the same age span (11-13 years) that was identified by Epstein (1986) as a period of rapid brain growth using measurements of head circumference and EEG energy found in the α range (8-13 Hz). If this speculation holds up, duration of the motion aftereffect could supply another valuable measure of brain growth.

REFERENCES

Andersson, A. L., & Ruuth, E. (1971). Relation between spiral aftereffect duration and rod-and-frame test performance in early childhood. *Perceptual & Motor Skills*, **32**, 843-849.

Andersson, A. L., Ruuth, E., & Ageberg, G. (1977). Patterns of perceptual change in the ages 7 to 15 years: A cross-sectional study of the rod-and-frame test and the spiral aftereffect technique. *Scandinavian Journal of Psychology*, **18**, 257-265.

Beverley, K. I., & Regan, D. (1979a). Separable aftereffects of changing-size and motion-in-depth: Different neural mechanisms? *Vision Research*, **19**, 727-732.

Beverley, K. I., & Regan, D. (1979b). Visual perception of changing-size: The effect of object size. *Vision Research*, **19**, 1093-1104.

Bhattacharyya, A. K., & Chattopadhyay, P. K. (1981). Spiral aftereffect and intelligence: A correlational study. *Child Psychiatry Quarterly*, **14**, 34-37.

Cavanagh, P., & Favreau, O. E. (1980). Motion aftereffect: A global mechanism for the perception of rotation. *Perception*, **9**, 175-182.

Epstein, H. (1986). Stages in human brain development. *Developmental Brain Research*, **30**, 114-119.

Harding, G. F., Glassman, S. M., & Helz, W. C. (1957). Maturation and the spiral aftereffect. *Journal of Abnormal & Social Psychology*, **54**, 276-277.

Harris, J. P. (1983). Age, sex, and time of day effects on the duration of the movement after-effect. *British Journal of Psychology*, **74**, 233-238.

Hershenson, M. (1985). Thirty seconds of adaptation produce spiral aftereffects three days later. *Bulletin of the Psychonomic Society*, **23**, 122-123.

Hershenson, M. (1988). Inspection duration and the linear motion aftereffect: Preliminary report. *Bulletin of the Psychonomic Society*, **26**, 221-224.

Hershenson, M. (1989). Duration, time constant, and decay of the linear motion aftereffect as a function of inspection duration. *Perception & Psychophysics*, **45**, 251-257.

Masland, R. H. (1969). Visual motion perception: Experimental modification. *Science*, **165**, 819-821.

Regan, D. (1986). Visual processing of four kinds of relative motion. *Vision Research*, **26**, 127-145.

Regan, D., & Beverley, K. I. (1978). Illusory motion in depth: Aftereffect of adaptation to changing size. *Vision Research*, **18**, 209-212.

Regan, D., & Beverley, K. I. (1985). Visual response to vorticity and the neural analysis of optic flow. *Journal of the Optical Society of America A*, **2**, 280-283.

Taylor, M. M. (1963). Tracking the decay of the aftereffect of seen movement. *Perceptual & Motor Skills*, **16**, 119-129.

NOTE

1. One subject, the oldest, was eliminated from the regression analyses because his behavior was erratic. The slope of his regression line was more than two standard deviations from the mean.

(Manuscript received November 13, 1989.)