of I^{125} to I^{131} for each spot was calculated. The patterns for the digest of the mixture of the two iodinated proteins or the digest of the reduced and alkylated, but unfractionated, mixture were essentially the same. The results for both digests are shown at the top of Fig. 2. For most of the spots the ratio of the amount of I^{125}- to I^{131}-labeled iodine was essentially unity, that is, it was the same as in the original mixture. However, the ratio for three of the spots was high, indicating that more of the iodinated peptides represented by these spots came from the antibody iodinated (I^{125}) in the absence of hapten than from the antibody combined with hapten during iodination (I^{131}) (*6*).

The amino acid sequences from which these latter iodinated peptides were obtained are apparently closely associated with the combining site since their rate of iodination was greatly decreased by the presence of hapten blocking the site; however, peptides with a high ratio not from the site could come about by a conformational change taking place on combination of antibody with hapten, if such a conformation change caused a decreased rate of iodination of residues elsewhere than in the site.

Peptic digests of fraction B from the same iodinated preparation showed these same three high-ratio spots (Fig. 2). They were absent in the digests of fractions A_1 and A_2 except for a very slight amount of radioactivity in a position corresponding to one of the spots (No. 26) which showed a slightly increased ratio in the digest of fraction A_1 (*7*). Moreover, the digests of fractions A_1 and A_2 gave no spots showing a particularly large deviation from unity in the ratio (*8*).

These results show that the high-ratio peptides are from B chains rather than from A chains and that the binding of hapten by antibody affects primarily the iodination of the B chain. If the high-ratio peptides are indeed from the binding site, the B chain forms at least part of the site. If the high ratios are due to a conformational change, the binding site can be in either chain with resultant decreased reactivity of the B chain towards iodination (*9*).

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6. The iodinated residue from these spots has been isolated and identified as diiodotyrosine. [O. Roholt and D. Pressman, *Federation Proc.* **22**, 556 (1963).]
7. This was probably due to a trace of residual unsplit antibody. The fact that this spot was not found in fraction A_2 gives some indication of the completeness of separation of B from A_2.
8. The largest deviation was attributable to spot A (Fig. 2) found in both digests with a ratio only one-fifth that of No. 26 or No. 27. Nothing was found in the corresponding position of the peptide pattern from fraction B. The corresponding spot in the pattern from whole antibody did not show elevated ratios (spot A, Fig. 2).
9. We thank J. V. Gurreri for technical assistance. Supported in part by the National Institute of Allergy and Infectious Diseases, grant AI-03962.

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Maturation of Performance with Space-Displaced Vision

Abstract. *This study tests two specific hypotheses of neurogeometric theory: that a critical period in maturation of space-displaced visual feedback in behavior occurs in childhood, and that a differential organization of inverted, reversed, and inverted-reversed visual feedback in motion will be found at the time when children are first capable of giving compensatory response to the spatial disorientation of vision. In keeping with theoretical expectations the results showed that when the different inverted and reversed feedback conditions could be performed, the response to the inverted feedback condition was the poorest, while that to the reversed condition was the most effective.*

The apparatus used consisted of an industrial RCA vidicon camera (TV-Eye) unit and a 21-inch portable television monitor, which together comprised the closed-circuit television system, and an electronic hand-writing analyzer (*1*). The camera was mounted directly over the work area. A dove prism affixed to its lens was used to displace the visual field. The feedback image was of normal size. The electronic handwriting analyzer was used to time the duration of the manipulative and travel components of writing, drawing, and dotting motions.

In this controlled situation, a cloth curtain hid the subject's movements from his direct vision, so he had to control them by watching the television monitor.

Each subject performed three tasks under four different visual feedback conditions, namely, with normal vision and with righ-left reversed, inverted, and inverted-reversed feedback. The task was performed in a compensatory way. This means that the subject had to reorient the direction of his drawing, writing, and dotting motions so that the patterns made always appeared normally oriented on the television monitor. Each subject began with the normally oriented feedback and was then given the other three conditions in random fashion. The subjects made rows of dots, wrote *a*'s, and drew right triangles with the right angle in the lower left-hand corner (*2*). Five characters were made in a row and four rows were written or drawn under all four visual-feedback conditions. The electronic motion analyzer timed the contact and travel movements separately in each trial to 1/100 of a second.

The subjects were 36 parochial-school boys ranging in age from 9 years 6 months to 13 years 6 months. All were of normal intelligence and behavior for their grade level.

Of the 36 boys who started the experiment, only 12 were able to complete the tasks under all four conditions of visual displacement. In keeping with our assumptions, there was a definite age factor in the ability to respond to the different conditions of displacement. That is, there appeared to be a fairly definite break at about age 12 between those who could do the tasks and those who could not.

Of the 15 boys aged 9, 10, and 11, there was only one who could perform under all four conditions of feedback. Of the 21 boys aged 12 and 13 years, there were 11 who could perform under all four conditions successfully and ten who could not. The difference between these two age groups was significant at the 5 percent level, using a corrected chi-square test for small frequencies.

The age-break in performance just described appears even clearer when the following results are considered. Of the ten boys aged 12 to 13 years who failed, five of them were able to do all but the inverted condition. This contrasts with only four of the 14 younger failures who were able to do all but the inverted condition. Of these five failures aged

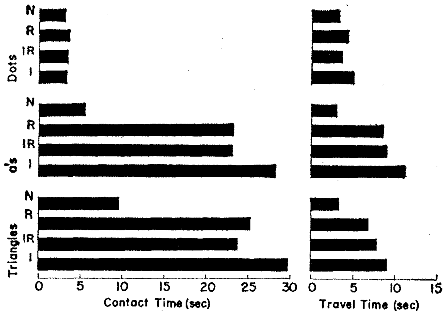

Fig. 1. Differences in response to different displacement conditions just after the critical period in development of the ability to perform under different conditions of inverted and reversed visual feedback.

12 to 13, four were able to make the inverted *a*'s but failed on the inverted triangles. None of the younger failures were able to make either inverted *a*'s or triangles.

Figure 1 shows the contact and travel times for the 12 subjects who completed all four visual conditions. Analyses of variance of the contact and travel times showed that there were significant differences between conditions. Subsequent tests found that the normal condition was the easiest, the reversed and inverted-reversed significantly harder than the normal but not different from each other, and the inverted condition significantly harder than the other three. Figure 1 shows also that the task of making triangles resulted in times of movement longer than either of the others.

The results conform to the expectations that guided the design of the study. That performance was related to age suggests that maturational factors may be involved in the behavior. The additional demonstration of differential organization and effectiveness of the response to inverted, reversed, and inverted-reversed vision provides systematic evidence that this developmental change is maturationally organized in terms of anistropic properties of the visual-feedback mechanisms of response.

The findings are of interest in relation to other studies which have suggested that a critical developmental period in behavioral or perceptual organization occurs sometime between the ages of 10 and 12 years. This period generally corresponds with the time at which relational thinking (*3*) and concepts of social relations (*4*) are believed to develop in the average child. Piaget (*5*) indicated that symbolic thinking developed around the years of 10 to 12. We believe this is also the time when handedness is stabilized in the child, and the beginning phase of highly refined manipulative skill.

The results are also of interest in relation to findings on development of perception (*6*) of the moon illusion, namely the decrease in apparent size of the moon as it moves from horizon to zenith; this development varies with chronological age, and reaches an adult level at about 10 or 11 years of age, and is attributed (*6*) to a learning process. The present results suggest this perceptual development may not be related to learning but to intrinsic development in the neurogeometric organization of the direct and compensatory reactions to displaced vision.

Overall, the findings suggest that maturational studies of space-displaced and delayed visual feedback in behavior (*7*) provide a fresh general area of experimental analysis of the development of organized behavior in the child. Interest is now being extended to maturational studies of reading, body-movement control, and to manual operations other than writing and drawing.

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6 May 1963

Stimulus Polarity and Conditioning in Planaria

Abstract. *Orientation in the monopolar pulse field used as the unconditioned stimulus was found to influence formation of a conditioned response to light in planarians. Planarians trained while oriented with the head toward the cathode reached maximal response rates rapidly, while those trained while oriented toward the anode showed no evidence of conditioned response formation.*

Recently it has been demonstrated that planarians can form conditioned responses in a classical light-shock conditioning situation (*1, 2*). These reports have suffered from a lack of precise definition of the physical variables of the experimental procedures, such as light intensity and the parameters of the electrical stimulus used.

It has already been shown (*3*) that light is not a neutral conditioned stimulus (CS) but can act as a weak aversive unconditioned stimulus (UCS), as might be expected from the negatively phototropic habits of planarians (*4*). Fortunately, most publications in this area have described the experimental equipment in sufficient detail to permit ready duplication of the CS.

Since these organisms have long been known to be strongly galvanotropic (*5, 6*), a thorough understanding of the electrical UCS used in conditioning experiments such as those referred to (*1, 2*) seemed equally essential to good experimental design. Unfortunately, these publications listed only the input voltage to the device used (the Harvard Inductorium) and gave indication of neither output voltage, nor, in some cases, the current density.

The purpose of this study was to define the effect of orientation in a monopolar UCS field on acquisition and retention of a conditioned response to light.

Planaria (species *Dugesia tigrina*) (*7*) were maintained in spring water at room temperature in the dark (except during conditioning trials) and were used within 7 days of receipt from the supplier.

The test apparatus and procedure was modified from that described by McConnell, Cornwall, and Clay (*8*). The trough was 30 cm long and was filled with spring water to give a right-triangular cross-sectional area of approximately 0.5 cm^2. Average level of illumination of the trough between trials was 0.17 ft-ca (about 1.87 lu/m^2) from an indirect 80-watt fluorescent unit 15 ft (about 4.57 m) away. The CS was provided by two 100-watt bulbs centered 6 inches (about 15.24 cm) over the trough, which produced an illumination of 1300 ft-ca (about 14,000 lu/m^2) during each trial.

A study of the waveforms produced by a Harvard Inductorium as used in previous studies (*1–3*) to provide the UCS showed that no control of pulse