Habituation of the visual orienting response in young children

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The eye tracks of 29 children (aged 2-7 years) were recorded by a reflection eye camera while they were looking at a 4 by 4 matrix of 16 white geometric shapes. When a circle suddenly changed to red, the children immediately looked at it for two-thirds of the presentation time, a reading which was 16 times the initial level before this novel color was introduced. With repeated presentations of the novel red circle display, progressively fewer fixations fell on the red circle. After 20 trials, this habituation was incomplete, and the red circle was still drawing six times the initial amount of looking found on the original white circle. Ss were apparently relatively slow to form a neural representation of the visual environment due to the wide range of choices in the original display. The age of the children had no monotonic effect on the high, and virtually equal, initial visual concentration, nor on the rate at which habituation occurred. An interesting contrast, therefore, appeared between these data and the marked age effects noted by others in the recognition of letter-like shapes. Unlike recognition tasks, orienting and habituation need a minimum of stimulus interpretation. Children, even as young as 2 years, have demonstrated a remarkable efficiency in these processes of orienting and habituation to novelty.

When undertaking this study, we had two main objectives in mind. Our first intention was to try to clarify the nature of the orienting response. Specifically, we felt that the data on the visual orienting response lacked any hard evidence in distinguishing directly between two different ways in which orienting can improve visual performance. We wished to see whether the orienting effects rested on a heightened general alertness alone or whether they also depended on a focusing of attention on a limited area of the scene. Does the visual orienting response have only a general facilitatory effect on the brain and retina? Alternatively, do the outgoing cerebral impulses accompanying attention have a further effect? Do they act on the eye muscles so precisely that the gaze picks out any novel feature from many potential cues? Is there such a process as perceptual attack as well as perceptual defense?

Despite the general significance of such questions, no one has so far measured the exact directionality of the gaze in choosing between many alternatives during the visual orienting response to novelty. This may seem surprising, since Leckart and Faw (1968) have recently listed as many as 116 references on the visual orienting response. In fact, no one has so far recorded the visual choices made in tasks that have many quite separate stimuli; all of these are potential cues, but suddenly one of them changes. This situation seems more like the events of every day than do the experimental circumstances on which the existing evidence is based: the latter are usually situations in which the S is choosing between only two alternative scenes.

We, therefore, thought it important to permit choice between as many as 16 alternatives in the display, since it seemed so likely that visual novelty did give more than general arousal effects. For example, from earlier experiments, we already knew that the line of sight falls within 1 deg of important details, even during the apparently casual scanning of ordinary representational pictures (Mackworth & Morandi, 1967). The wide-angle reflex eye camera assists the conduction of this type of study, since it gives a simple method of recording the visual selection of one item in a complex display (Mackworth, 1968).

Since it is not necessary to fix the head rigidly by using a bite bar, this technique has proved feasible with children as young as 2 to 3 years old (Vupillot, 1968; Mackworth & Bagshaw, 1969).

Our second main objective was to use the visual orienting response to start a series of developmental studies. Our general theme here was that experience during the first decade of life could be regarded as giving opportunities to learn cerebral programs to evaluate stimulus differences. The visual orienting response to novelty and its habituation were therefore of greater interest as a starting point for this research program, since such activities entailed a minimum of stimulus interpretation. Even young Ss have had many opportunities to respond to novelty in the past: from birth, each new event has had to be scaled for importance. "Is it new?" is a question that often needs little interpretation. On this basis, we thought that orienting to simple novelty would not be much affected by the age of the children, since responses to novelty are so basic to life.

We did expect, however, that age would alter the rate of habituation to novelty because the cerebral program needed to evaluate the stimuli now asks two questions (rather than one): "Is it new?" and "Is it important?" We expected

![Fig. 1. Eye-camera close-up of a child selecting a square from the 16 available stimulus symbols.](image-url)
that this increase in the complexity of the stimulus-evaluation program would be sufficient to lead to age differences in habituation. We thought that the more complex program would give the older children more opportunity to demonstrate their greater skill at linking external events to relevant stores of experience, and, therefore, that they would show faster habituation to novelty.

The specific objectives of the present study concerned the examination and measurement, with young children of different ages, of three general aspects of their visual behavior: (1) the visual orienting response (VOR) to novelty; (2) habituation of the VOR during repetitive presentation of the "novel" stimulus; (3) Dishabitation of the VOR following removal of the "novel" stimulus and reinstatement of the original stimulus display.

METHOD

A wide-angle eye camera, previously described by Mackworth (1968), was used to record the position of the gaze of Ss on a static visual display. In this technique, an image of the stimulus display reflected off the pupil of the right eye was recorded by a motion-picture camera at the rate of five frames/sec. The locus of gaze was later determined by noting which part of the stimulus display was centered in the pupil in each frame. Figure 1, for example, shows one typical motion-picture frame taken from a child looking at a square symbol in the left column of the array.

The stimulus display consisted of a 4 by 4 matrix of simple white geometric shapes in a black field; these patterns were presented vertically in a rectangular viewing box. Each shape subtended 6 deg of visual arc. The 16-symbol matrix was organized in a balanced pattern of eight different shapes, each shape appearing once in the upper and once in the lower half of the display.

Visual stimuli remained exactly the same throughout the experiment, with the exception of a single item designated the test circle. This changed from white to red between the first and second phases of the experiment to provide the "novel" stimulus; it later returned to white before the final phase. The test circle was located in the third column, in the bottom row (see Fig. 1). As far as the S was concerned, the display was seen in a series of 40 brief presentations, undifferentiated except by these sustained color changes in one item.

control. Each phase consisted of 10 trials. A 3-sec presentation of the display followed by a 5-sec pause constituted a trial. The only difference between the phases was the change in the test circle from white in the first phase, to red for both Tests 1 and 2, and then the change back again to white in the final posttestcontrol phase. No elaborate searching was required because the position of each display symbol remained unchanged throughout the experiment. The procedure was, therefore, intentionally planned to be different from that used by Vulpilot (1968) because she has already clearly established that 3-year-olds are very deficient compared to older children at systematic search for visual stimuli.

No chinrest was required with the equipment. Ss were asked to lean their heads against a padded foreheadrest, mounted on the viewing box, and to look at the pictures without moving their heads. With some 2- to 3-year-old children, E gently held the head of the S against the foreheadrest. At the start of the run, E modeled the desired behavior of peering into the viewing box with these very young Ss.

Subjects

The experimental data have been obtained from a sample of 13 boys and 16 girls, ranging from 2 years 7 months to 7 years 6 months, tested in the campus nursery school. (Three test records were discarded as not being sufficiently readable.)

Scoring Method

Since the number of readable frames per trial varied between Ss, an arbitrary unit of analysis was chosen. This unit was a block of 20 frames that showed the line of sight on the matrix display. Grouping data in this manner yielded five blocks from the 10 trials in each phase (two trials per block).

Visual orienting responses were assessed in terms of the fixation index, which was the percentage of motion-picture frames showing a fixation falling on the test circle within a block of frames. The fixation index was, therefore, derived from the number of such frames showing visual selection of the test circle divided by the total number of frames in the block. The total was obtained from 20 on-matrix frames plus any interspersed off-matrix frames. The fixation index was therefore a measure of the relative interest shown in an item regardless of whether or not the item was the test circle.

RESULTS

(1) VOR and Novelty

Figure 2 shows the fixation index in successive blocks. The fixation index started from a pretest control level of 4%, when there was no color difference between the white circle and the other symbols, and then rose to a mean level of 67% during the first block of Test 1, when the test circle appeared red. There was, therefore, a huge (initial orienting response to the novel red circle. This early incidence of fixations on the red circle was 16 times the pretest level. All but 1 of the 29 Ss showed an increased fixation index as soon as the circle changed to red. We see below (in Section 3) how all the Ss eventually showed this marked visual concentration on the novel area, since our expectation was soon noticed the changed symbol.

(2) Habituation of VOR

Figure 2 further illustrates a dramatic decrease in the percentage of time spent viewing the red test circle during successive blocks of Test Phases 1 and 2. One minute of viewing time for the red test circle (consisting of 20 3-sec presentations of the red test circle spread over a period of 160 sec) produced a drop in fixation index from a mean of 67% to 25%. Even so, Ss were still orienting to the red circle at a level higher than chance in the final block of Test Phase 2. The fixation index was significantly higher in this final block than it was in the final block of the pretest phase (T = 28.5, N = 23, p < .01, Wilcoxon matched-pairs signed-ranks test; Siegel, 1956).

This prolonged interest in the red circle confirmed the views of Watson (1969) that looking has its own reward which reinforces the position of the rewarding item as well as the nature of the symbol itself; the resulting side-effect of such reinforcement is a temporary positional preference that may continue to affect visual choice after the reinforcing situation has been removed.

(3) Age and VOR to Novelty

We thought that age might have no effect on orientation to novelty, and Fig. 3 supports this view. The task involved little in the way of interpretation, since it was mostly stimulus acquisition and storage of the data under the labels of novel or not novel. The initial effect of something new in the display produced an overwhelmingly large effect with all the age groups. Before the new color appeared, the age scores (which averaged 4%) were 5%, 2%, and 6%, respectively, for the 2-, 3-, and 4-year-old groups.
(4) Age and Habituation of VOR to Novelty

After the above initial effects of novelty, the highly attractive nature of the red circle began to wear off. But the downward slopes of these habituation curves were the same in all age group, the regression lines (Table 1) showed no significant differences. The general level of height of the lines did differ slightly with age; the youngest children (2 to 3 years) looked rather longer at the red circle than did the middle group (4 to 5 years) (see Table 2 and Table 3). A second analysis of these two younger groups alone confirmed the statistical reality of this difference between these two age groups (p < .01 and p < .001).

The details of these statistical analyses were as follows: Group A contained five boys and six girls aged 2 to 3 years; Group B consisted of seven boys and four girls aged 4 to 5 years; and Group C had one boy and six girls aged 6 to 7 years. In the first analysis of variance, four groups were randomly eliminated from both Group A and Group B, leaving seven in each group. Results are presented in Fig. 2 and in Tables 2 and 3. The main effects of the variables of age and experimental conditions were highly significant (age: p < .01; test phase: p < .001), with no significant interactions. Table 4 gives the second analysis of Groups A and B only (N = 11 per group) and this confirmed the findings for the two younger groups. Both main effects were significant (p < .001) and there was no significant interaction.

The oldest group (Group C, 6 to 7 years) showed fixation scores for the novel color that closely resembled those for the youngest group (Group A, 2 to 3 years). No simple explanation for this U-shaped relationship between age and orientation can be advanced without further experiment. Some might imagine that it was related to the imbalance of sexes in Group C, but we think this interpretation most unlikely because no sex differences were found during this pretest control phase or during the red circle test phases of the experiment.

(5) Dishabitation of VORs

More than chance attention was still being paid to the bottom test circle after it had returned to white in the final set of trials. Table 2 shows that the average fixation index in the final white-circle display was 17. Again, this was a reliable increase over the first white-circle reading of 4% (p < .01). The unexpected finding was that those looking longer on the test circle were almost entirely due to the boys rather than to the girls (Fig. 3). A further analysis of variance was undertaken on 10 boys and 10 girls from the two youngest groups. The analysis showed no overall effect of sex on the scores, but again there was an interaction between sex and conditions (p < .005, F = 3.3, df = 3/72).

This interaction was due to a difference between boys and girls in the fourth experimental condition with the final white-circle display. Then the boys spent 23% of the time inspecting the circle, whereas the girls spent only 8% (see
Table 2
Looking Time on Test Circle

<table>
<thead>
<tr>
<th>Circle Color</th>
<th>Pretest White</th>
<th>Test I Red</th>
<th>Test II Red</th>
<th>Post-test White</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-3</td>
<td>4.9</td>
<td>49.8</td>
<td>33.8</td>
<td>22.0</td>
<td>27.5</td>
</tr>
<tr>
<td>4-5</td>
<td>1.9</td>
<td>37.8</td>
<td>15.9</td>
<td>13.5</td>
<td>17.3</td>
</tr>
<tr>
<td>6-7</td>
<td>5.8</td>
<td>50.3</td>
<td>28.6</td>
<td>16.1</td>
<td>25.2</td>
</tr>
<tr>
<td>Means</td>
<td>4.2</td>
<td>46.0</td>
<td>25.9</td>
<td>17.2</td>
<td></td>
</tr>
</tbody>
</table>

(Mean Fixation Index—percent of total looking time)

Table 3
Analysis of Variance of Data in Table 2

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>ms</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Group</td>
<td>2</td>
<td>803</td>
<td>7.14</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Phases</td>
<td>3</td>
<td>6447</td>
<td>57.3</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Interaction</td>
<td>6</td>
<td>91</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td></td>
<td>72</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>82</td>
<td>12720</td>
<td>N.S.</td>
<td></td>
</tr>
</tbody>
</table>

Table 4
Analysis of Variance of Age Comparison Between 2-3 and 4-5 Only (N = 11 for Each Group)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>ms</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Group</td>
<td>1</td>
<td>2199.2</td>
<td>25.5</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Phases</td>
<td>3</td>
<td>6279.9</td>
<td>72.88</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Interaction</td>
<td>3</td>
<td>155.5</td>
<td>1.8</td>
<td>N.S.</td>
</tr>
<tr>
<td>Error</td>
<td>80</td>
<td>86.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3. At the beginning of this phase, the first pair of trials showed an even greater difference, since on this block of trials the boys averaged 42% and the girls only 12% on the initial pair of trials (t = 3.85, df = 18, p < 0.005). No other sex-difference effect was noted in the entire experiment, so this was not due to any difference in color vision. Our evidence that the boys were more interested than girls in the final color change of the test circle may be related to the finding reported by Hahs, Miller, and Spitz (1963) that normal 8-year-old boys had more perceptual curiosity than girls of that age when such Ss could request either complex or simple patterns during a viewing spell. Their evidence was that boys chose the complex designs twice as often (50% of occasions) as did the girls (25%). But no such sex difference was found in Ss aged 17 years.

DISCUSSION

(1) Cerebral Control of the Line of Sight

The present study underlines the very marked effects of novelty on the orienting activity of the visual-receptor organs. Typically, the visual orienting response entails the precise aiming of the eyes at one particular part of the stimulus scene. Stimuli are, however, not merely changes in simple input-output theories of behavior are clearly quite dead because the brain perceives what it allows itself to perceive (Bartlett, 1932). The organism has considerable control over potential stimulation, since certain stimuli are given significance above others. Experience is therefore usually being very selectively sampled; for instance, comparisons are constantly being made between intended plans and actual achievements (Miller, Galanter, & Pribram, 1960).

The afferent and efferent pathways between the brain and peripheral receptors are known to provide two-way communications. Repeat, peripheral pathways are not one-way channels. The optic nerves carry many fibers for messages passing outwards from the brain to the retina (Spinelli & Pribram, 1967). These enable the organism (actively) to tune into the most relevant visual aspects of the environment and thereby control the input to the brain via the retina (Pribram, 1960; J. J. Gibson, 1966; Pribram, 1969). The ongoing impulses to the eyes have a further function, which is equally important because they also precisely aim the eyes at any new and important details in the environment. This process could be termed perceptual attack. This is a method of giving priority to important, stimuli by literally focusing these details on the foveas and by blurring out the rival, but less important, stimuli. Cerebral inadequacies of various kinds are now known to impair this process, as in the faulty visual sampling recorded in patients with aphasia (Mackworth, Grandstaff, & de la Pena; Tyler, 1969). Similarly, we also now know that 6-year-olds are less able than adults to find the informative areas in out-of-focus scenes. Children cannot draw on experience as much as adults do, to guide them towards the most significant areas in the pictures (Mackworth & Bruner).

(2) Relation Between Age and the Orienting and Habitation Changes

The fact that all our age groups initially showed such a very marked and visually equal orienting response to novelty was not too surprising since the data-processing involved in orienting is so simple that little is needed to program the input signals in order to achieve the required visual selection. Therefore, we conclude that 2-year-olds orient just as effectively as 7-year-olds.

We were, however, somewhat surprised to find that increasing age does not alter the rate at which the group fixation times declined during the habituation phase of the experiment. This result indicated that children between the ages of 2 and 7 were equally able to process and to
the orienting phase, the children in this experiment were classifying the stimuli into novel or not-novel, and during the habituation phase they were also categorizing the stimuli according to a judgment of important or unimportant.

Our own evidence makes a remarkable contrast with the interesting and definite age effects found with the performance studies on the recognition of letter-like forms by Gibson, Gibson, Pick, and Osser (1962), also on campus nursery-school children. These experiments on the discrimination between various letter-like forms showed that accuracy improved considerably between the ages of 4 and 8 (provided the transformations being tested were critical for discrimination between one distinctive feature and another). Recently, Spring (1965) has noted that such tasks of upper-case letter recognition entailed quite an elaborate psychological process that often involved as many as eight possible classification rules to recognize the pattern of lines forming each letter. We therefore conclude that greater difference between age groups may be expected on performance scores when more elaborate programming is needed to interpret the stimuli. For example, Reese (1968) has described many stimulus-transformation tasks that show considerable developmental changes within the age range we studied.

(3) Habituation Delay Due to Many Choices
The detailed nature of our 4 by 4 matrix, in terms of the number of available symbols, may have been responsible for the somewhat more prolonged downward trend in the present studies. Note that the decline was still continuing in the final data from the red circle condition (Fig. 2). Cantor and Cantor (1966) also reported a relatively protracted decline in viewing time for 108 kindergarten Ss with repeated presentations; the slow decline they found was perhaps also due to the numerous details in the black-and-white drawings they used as stimulus material. Similarly, Thomas (1966) obtained longer looking times when children aged 6 to 12 were looking at more complex patterns. It is tempting to speculate that greater numbers of details demanded more looking time because their Ss were taking longer to form some internal neural model of the more detailed external events. Certainly, in our study, the idea of a gradual formation of such a neural representation would be consistent with the slowly declining trend we found in the fixation time on the red circle.

(4) Age differences within this range had no effect on the rate at which the children habituated to novelty; all three age groups showed the same slope for the decline in the fixation incidence on the novel item. (Slight differences were, however, noted between the age groups as regards the absolute level of their fixation incidence during the habituation phase; the reasons for this are still unknown.)

(5) This similarity in the rate of habituation to a single stimulus of the different age groups suggests that even 2-year-olds can readily undertake stimulus transformations that require only very simple cerebral programs. Two-year-olds are as effective as 7-year-olds when the questions at issue are no more than: "Is it new?" "Is it important?" This result on visual orienting to novelty and its habituation is quite different from the marked age effects found for letter recognition by other investigators studying children of comparable age. The key difference here between the tasks is that recognition tasks require up to as many as eight classification rules for the recognition of each stimulus letter. We conclude that the much simpler visual tasks involved in the visual orienting and habituation situation do not tax the brain to any extent, and therefore, they do not reveal differences between age groups. But more complex tasks, such as letter recognition, depend upon the use of more rules in the required cerebral program and are therefore much more likely to reveal age differences by favoring the older children.

(6) The children we tested were relatively slow to habituate, as compared to other data from earlier workers, with such simpler stimuli as repetitive tones or flashes of light. After 20 3-sec trials with the novel-item display, this red circle was still being visually selected 6 times more often than it had been originally when it was white. One possible reason for this rather slow habituation was the relatively large number of alternative items in our display.

(7) Boys, aged 2 to 5 years, showed noticeably more perceptual curiosity when the novel coloring was removed from the red circle. They started to look at the circle more often when it returned to the white color, as compared with the last red trial; the girls of the same age showed no such dishabituation. This difference may be related to the known fact that boys about this age are more inclined to ask for complex patterns when free to request either simple or complex displays in a perceptual task.

(8) It is now time for VOR studies to move on to more complex patterns of stimuli, which approximate reality more closely, by providing more available choices than the either/or, two-choice problem. If the slower habituation is an indication of the time required for making neural models of such situations, this type of experiment, with as many as 16 choices, may give a useful quantitative measure of such more complex mental processes.

(9) The direct head-on study of the cognitive processes is so difficult that we can get to
understand the attentive functions of the skilled brain. Part of that help can come from the line-of-sight recordings, which reveal the track made by the eyes across a specific scene containing many alternatives. Recording the visual orienting response (VOR) and its habituation allow us to follow the formation of a neural model of the environment and its subsequent use in reaching decisions.

(10) Clearly, the attentive processes entailed by the visual orienting response to novelty consist of much more than general facilitative effects on cerebral function. Outgoing impulses from the brain to the oculomotor muscles also guide the eyes and aim their foci precisely at the novel item. This visual aiming is not merely a parallel process occurring at the same time as the generalized cerebral alertness. This perceptual attack on the novel visual stimulus is an active and essential link in the whole circular process of selective attention. Considerable emphasis is thereby achieved between the various potential visual stimuli. Indeed, perceptual attack insures that visual details now judged to be important are literally featured in central focus, while current irrelevancies are being relegated to the outermost darkness of blur. So unobtrusive is this obvious selective process that it is all too easy to overlook its effective presence. But everyone filters stimuli with their eyes especially in the presence of novelty.

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NOTES

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