Perception & Psychophysics NLP-72K HP

Habituation of the visual orienting response in young children[1, 2]

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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 (Vurpillot, 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 ~~1st~~ 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

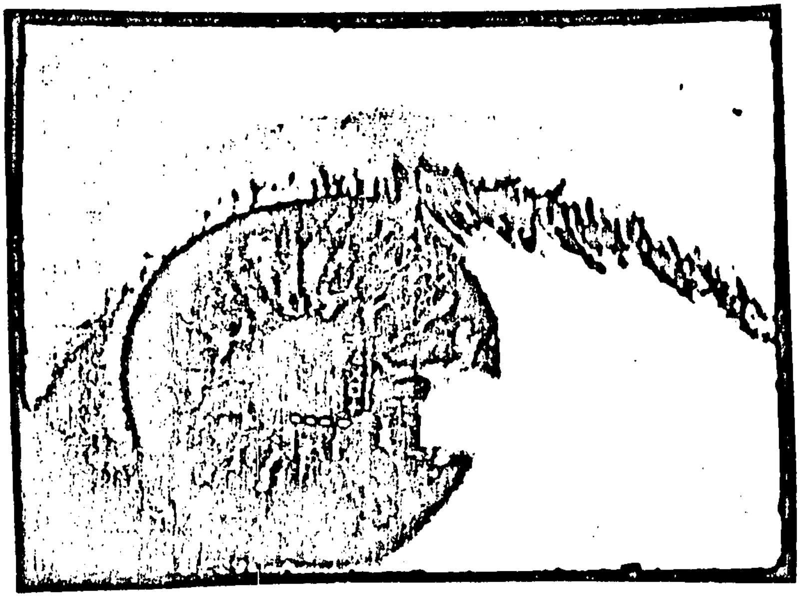

Fig. 1. Eye-camera close-up of a child selecting a square from the 16 available stimulus symbols.

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) *Dishabituation 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 of 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 posttest control 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 Vurpillot (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

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 exception also soon noticed the changed symbol ~~later~~.

and

omit

(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%, 35

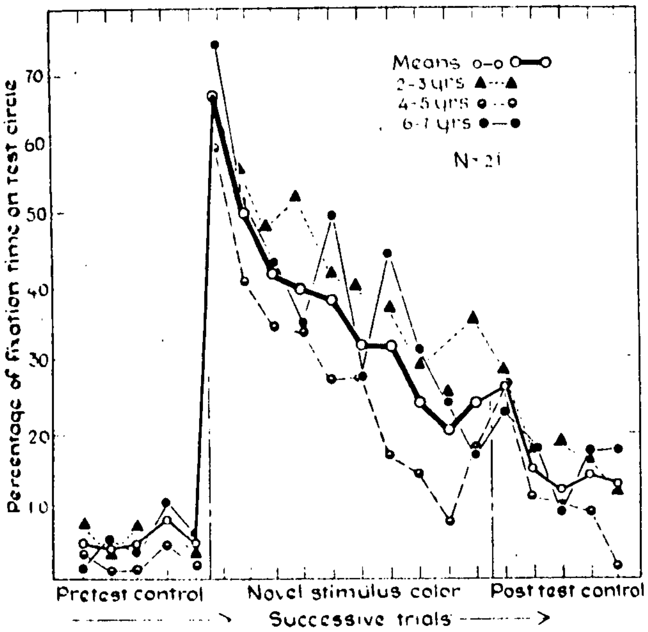

Fig. 2. Mean percentage of fixation time spent on test circle by the three different age groups—before the novelty, during the novel color, and after its removal.

Table 1

Slopes and Intercepts for Red Circle Phase for Three Age Groups; Relation of Percentage of Fixations on Red Circle to Successive Trials

Age Group	Slope	Intercept
	(b)	(a)
2–3	–3.82	63.3
4–5	–4.62	53.1
6–7	–4.64	64.9

A multiple-test gave the following values for differences between slopes: 2-3 vs 4-5, t = 0.8: 2-3 vs 6-7, t = 0.7: 4-5 vs 6-7, t = 0.01 (t = 1.98 for p < 0.05).

the initial novel response point in Fig. 3) were quite different, scores of 64%, 60%, and 74% being noted for these age groups. The middle group contained our one "exception," a girl who was so slow to orient that she scored 0% in the first red circle block but who also reached a typical 71% score in the third test block. This was a characteristic reading for that 4-to-5 age group because the scores for the remaining six Ss averaged 70% on the first two novelty trials.

(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 groups; 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 youngest 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 Ss 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) Dishabituation 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% ($p < 0.01$). The unexpected finding was that those looks lingering 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 younger groups. The analysis showed no overall effect of sex on the scores, but again there was an interaction between sex and conditions ($p < 0.05$, 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

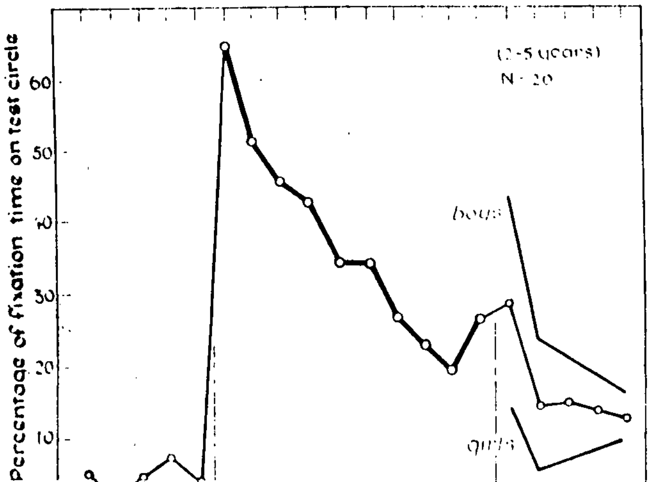

Table 2
Looking Time on Test Circle

Circle Color	Pretest White	Test I Red	Test II Red	Post-test White	Means
Age Group					
2–3	4.9	49.8	33.3	22.0	27.5
4–5	1.9	37.8	15.9	13.5	17.3
6–7	5.8	50.3	28.6	16.1	25.2
Means	4.2	46.0	25.9	17.2	

(Mean Fixation Index–percent of total looking time)

Table 3
Analysis of Variance of Data in Table 2

Source	df	ms	F	p
Age Group	2	803	7.14	<.01
Phases	3	6447	57.3	<.001
Interaction	6	91	0.8	
Error	72	112		
Total	83			

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

Source	df	ms	F	p
Age Group	1	2199.2	25.5	<0.001
Phases	3	6279.9	72.88	<0.001
Interaction	3	155.5	1.8	N.S.
Error	80	86.1		

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 Hoats, 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

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 outgoing 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 itals 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[4]; 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 omit scenes. Children cannot draw on experience, as much as adults do, to guide them towards the most significant areas in the pictures (Mackworth & Bruner[5]).

Some valuable parallels have recently been drawn by Fellows (1968) between the orienting responses of children and the two-response chain so characteristic of animal learning. He also reminds us that Spence (1940, 1951) noted long ago that animals must first learn to orient the head

elicited. An orienting response is therefore usually found before the more obvious and better known discrimination response.

Following Pavlov (1927), Sokolov (1963) and many others have recently also described the temporal association between cerebral selective attention and the peripheral orienting activity of the sense organ. But the nature of this relationship has been left so open that it could have included a general state of arousal and a simultaneous parallel process of visually focusing on important stimuli.

We have stressed the term, perceptual Itals attack, because this implies the idea that, selective attention and visual orienting are not merely happening together. The visual orienting response is an active and essential part of the perceptual process; it is not merely a concomitant by-product of selective attention. Neglect of this fact has been partly responsible for the current chaos in regard to selective attention. Not only is this a difficult topic, but not all possible means of investigating this subject have been employed. Nearly all the important experimental effort has so far been aimed at understanding directly the role of the cerebral processes themselves, with little regard for the evidence talt that might be obtained from an analysis of the visual orienting responses. Several quite recent publications have started to redress this imbalance (see, for example, Jeffrey, 1968; Cowan, 1968; Treisman, 1969; J. Mackworth, 1969, 1970).

In brief, we conclude that because orienting responses are such an integral part of the attentive process and not merely an adjunct, a far more intensive analysis of visual orienting activity could lead to a great deal of much needed data on the course and nature of selective attention.

(2) Relation Between Age and the Orienting and Habituation 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 also 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[6] 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 prese[illegible] studies. present 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 ~~the~~ omit 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.

(1963) regarded a much more

response to such very simple stimuli as light or tones. After the first few applications, the reaction was soon extinguished (Sokolov, 1963, p. 241). Similarly, the visual orienting response to repetitive tones disappeared after about the sixth tone (p. 203). In general, we believe that Sokolov underestimated the number of trials usually needed to habituate the visual orienting response, although he does indicate that the orienting reaction is more persistent when the differentiation of the stimuli is more difficult (p. 205). It is also quite possible that Sokolov's extremely simple stimulus situations did not really require accurate aiming of the eyes towards the stimulus. Then again, he was using adults as Ss rather than children. Whatever the exact reasons for the difference, it is clear that the decline in the visual orienting response lasted much longer in our own study during exposure to novelty than it did in previous studies with adults or children, where the number of visual choices have usually been limited to a ~~an~~ ~~either/or~~ two-choice response.

CONCLUSIONS

(1) Young children, aged 2 to 7 years, showed a marked visual orienting response (VOR) when one item in a group of white symbols was suddenly changed to red. The mean amount of time that each age group spent looking at this novel item increased 16-fold when the new color appeared. The use of many stimulus objects in the display made it easier to differentiate between this deliberate visual selection and idle scanning movements. This initial, heavy visual concentration on the novel items amounted to a total of about two-thirds of all the fixation time for all three age groups, aged between 2 and 7.

(2) Within this age range of 2 to 7 years, there were no significant differences due to age in regard to the extent of this initial, very extensive visual orienting response to novelty.

(3) Children of this age (even as young as 2 years old) showed a clear tendency to habituate, in the sense that they spent less and less time looking at the novel red circle when the display containing this single red item was shown repeatedly.

(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 situation for 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 just 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 many 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 six 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 even 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 all the help that we can get to

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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 foveas 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

1. We gladly thank Professor K. H. Pribram and Dr. M. H. Bagshaw for a great deal of advice and help during the course of these studies. In addition, we are indebted to Professor E. Maccoby for many useful suggestions, and also to Dr. E. Dowley for the considerable facilities at the Bing Nursery School, where Colleen Rand skillfully helped with the eye-camera recordings. Finally, we thank Dr. J. F. Mackworth, who assisted in the preparation of the manuscript.

2. This work was supported by NIMH Grant MH 12970 to the Neuropsychology Lsboratories in the Deaprtment of Psychiatry at Stanford University Medical School.

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(Accepted for publication June 20, 1969.)