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A New Slant on the Development of Orientation Perception

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A NEW SLANT ON THE DEVELOPMENT OF ORIENTATION PERCEPTION

by

Lynne Werner Olsho

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VITA

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INTRODUCTION

Numerous studies over the last fifty years have reported what Appelle (1972) refers to as the oblique effect in visual perception. It is difficult to define this effect precisely. In general it consists in the difficulty exhibited by a variety of organisms in the processing of lines presented at oblique orientations. The effect is, however quite pervasive: in humans it has been found that resolution of a line grating is poorest when the grating is presented at a 45^{o} orientation (Emsley, 1925). Furthermore, Sulzer and Ziner (1953) showed that subjects were less variable in their responses to vertical and horizontal lines than to obliques when asked to rotate another line to make it parallel to a standard. The effect has also been demonstrated in other animals, most notably by Sutherland (1957). Sutherland was able to train octopi to attack either a vertical or horizontal rectangle and to avoid one perpendicular to it, but was unable to train a positive vs. negative oblique discrimination under the same conditions. Sutherland (1958) found that vertical-oblique and horizontal-oblique discriminations were intermediate in difficulty.

A further aspect of the oblique effect in humans was first described by Rudel and Teuber (1963). These investgators attempted to train subjects aged three to eight years in a successive discrimination task in which the to-be-discriminated lines were vertical-horizontal and positive - negative oblique pairs. The results were that while all subjects had difficulty discriminating the oblique-oblique pairs, the younger subjects had comparatively greater difficulty on those discriminations. Rudel and Teuber (1963) also found that vertical-oblique and horizontal-oblique discriminations were as easily learned as the vertical-horizontal.

There has been a tendency to describe all of these effects as a single 'oblique effect.' However, this seems unlikely. On the one hand, it seems obvious that there is a sensory oblique effect. Beside the studies cited above (Emsley, 1925; Sulzer & Ziner, 1953), Campbell and Kulikowski (1966) showed that gratings oriented at 45° could be masked by gratings over a wider range of orientations than could vertical or horizontal gratings. Furthermore, Campbell and Maffei (1970) found that human visual evoked potentials (VEP) were of greater amplitude when the subject viewed a vertical or horizontal test pattern as opposed to an oblique one. However, some problems are encountered when sensory explanations are sought for the age x orientation interaction observed by, for example, Rudel and Teuber (1963). The development of orientation specific cells in the visual cortex has been characterized by early and presumably permanent establishment of a system of detectors (Blakemore & Cooper, 1970; Hirsch & Spinelli, 1970). In fact, more recent studies have suggested that the tendency for poorer resolution of obliques may be present at birth, at least in cats, and be relatively immune to the effects of visual experience (Leventhal & Hirsch, 1975; Stryker & Sherk, 1975). In humans, McGurk (1972) has shown that infants as young as six months of age were able to discriminate changes in orientation; Leehey et al. (1975) found that six week old infants preferred to look at vertical or horizontal gratings over obliques when the grating frequency was near the threshold of resolution. If, then, the orientation detector system is fixed at or shortly after birth, why should five-year-old human subjects discriminate oblique lines at a comparatively worse level than do adults?

Studies employing discrimination-type tasks, as a matter of fact, generally explain the poorer performance for five year olds on oblique discrimination as being due to some lack of conceptual or verbal skills on the part of young children (Gibson, 1969; Bryant, 1969; Over & Over, 1967). With the exception of the Rudel and Teuber (1963) paper described above, the sensory aspects of the phenomenon are generally ignored. It is with some surprize, then, that one finds Appelle (1972) describing all of these data in terms of a single oblique effect. On the contrary, it would seem that once one moves into the realm of matching-to-sample discrimination tasks, processes other than what one would call 'sensory' are involved, and may be responsible for the age x orientation interaction first observed by Rudel and Teuber (1963). Thus, studies such as Rudel and Teuber's may really be tapping into a double effect: a sensory deficit which is compounded by difficulties in what might be called encoding. By encoding is meant any transformation or reduction of the percept which is performed to enhance retention.

Before developing this argument further, it might be appropriate to describe in somewhat greater depth just what is meant by 'the' oblique effect and the hypotheses offered in explanation. On a strictly sensory level two questions have arisen, one as to the origin of the effect and the other as to its locus in the visual system. Studies such as those of Blakemore and Cooper (1971) and Hirsch and Spinelli (1971) in which kittens were deprived of visual experience except for exposure to lines in a single orientation seemed to indicate that experience is necessary for the development of cortical cells sensitive to specific orientations. This finding leads to the suggestion on the part of some (Mitchell et al., 1967) that the oblique effect in Western man is due to the disproportionate numbers of vertical and horizontal contours in our carpentered world. Support for this position is provided by Annis and Frank (1973) who failed to find an oblique effect in Cree Indians whose environment exhibits a wider distribution of contour orientations. On the other hand, Leventhal and Hirsch (1975) found that the superiority of vertical and horizontal contours over oblique ones may be present at birth and that visual cortex cells sensitive to verticals or horizontals do not require input in these orientations for their development. And as mentioned above, Stryker and Sherk (1975) found that later experience in a normal visual world did not affect the distribution of orientation selective cells, if visual experience were restricted for some time after birth by exposure to contour in a single orientation. However, these two positions need not be mutually exclusive if one assumes that what is affected by environmental input is the number of oblique detectors present.

As for the locus of the sensory oblique effect in the visual pathway, the evidence is not very clear. The question seems to be whether orientation is gravitationally or retinally referenced. Studies finding visual cortex cells in the cat which compensate for body tilt (Horn & Hill, 1969; Spinelli, 1970) appear to suggest a gravitational referent. However, a study by Frost and Kaminer (1974) found differences in the amplitudes of VEPs to horizontal, vertical or oblique gratings were reversed when viewed with the head tilted at 45°. This finding implies a retinal locus. Moreover, Rentschler and Fiorentini (1974) suggest that the cause of the oblique effect lies in differences in the degree of lateral inhibition occurring between units stimulated by lines of various orientations. The latter investigators presented a test line in either a vertical, a horizontal or an oblique orientation, together with a parallel subliminal inducing line. Detection thresholds for all three orientations were reduced in the presence of the inducing line; however, the reduction for obliques lines was significantly smaller than that for horizontal or vertical lines.

A further question regarding the oblique effect concerns whether it is due to the relative scarcity of cortical cells tuned to oblique orientations or whether oblique sensitive cells are less finely tuned than the others. Again an answer is not apparent. While the findings of Campbell and Kulikowski (1966) would imply differences in the degree of tuning, Hirsch et al. (1974) using a grating adaptation paradigm do not find such differences. In addition, the reduction in VEP amplitude for oblique gratings observed by Campbell and Maffei (1970) and by Frost and Kaminer (1974) argue for differences in the number of cells present. At any rate, it should be apparent that some sensory effect exists; however, its exact nature remains uncertain.

As for the encoding aspect of the oblique deficit, a number of hypotheses have been raised, primarily directed at explaining the observed age differences. All of these have in common a supposition that the effect occurs at some point in the system beyond the sensory input stage. As Stoy (1975) points out, from an information processing viewpoint, the processing deficit for oblique lines might occur at a number of different levels in the system. Three encoding-type hypotheses will be briefly disussed here.

The first might be called an attention hypotheses: subjects may be unused to using orientation as a discrimination cue, particularly with respect to differently oriented obliques. It is suggested, furthermore, that children simply don't attend to such information, so that it never gets beyond the sensory stage. Gibson (1962) proposes that children may never have needed to use orientation as a relevant cue for the discrimination of objects, while adults, who have had experience in activities such as reading, would have found it necessary to process orientation information, and would, therefore, be able to use such information when the situation warranted. Gibson assumes cues to be attended to, then, on the basis of their ecological validity, their utility as discriminators. In a situation in which the concept of object constancy regardless of orientation is adaptive, disregard for orientation is to be expected. One might object that infants as young as six months of age are able to discriminate a change in orientation (McGurk, 1972), but whether a situation in which a single orientation is presented repeatedly and then changed is comparable to one in which a variety orientations are usually present is questionable.

A second possibility is that while children attend to orientation, either their processing strategies are inefficient with respect to orientation or they process information so slowly that they lack sufficient time for orientation processing. If one means by inefficiency a disorganized scanning strategy, evidence for such a deficit is of questionable value in the case of single line stimuli, as studies indicating such a problem (e.g., Braine, 1972) of necessity employ more complex figures than single lines. It would be possible to hypothesize, though, that children exhibit slower processing rates. If one assumes a view in which different stimulus dimensions are processed serially, it might be proposed that orientation is low on the list of dimensions to be processed. There are data in support of the notion that stimulus dimensions tend to be processed in a relatively stable order (Odom, 1972). The same study showed that processing orders might change with age, implying that even if no age differences in rate of processing were found, a difference in the position of orientation as a dimension in the processing hierarchy might account for the differences between five year olds and adults. The problem with this approach is that it doesn't really account for the effect observed. While it may be possible to suggest that because obliques take longer to process for some reason, and therefore are not discriminated very well, there is no way to explain why children should perform at a lower level on the obliques in relation to their overall preformance than the adults do.

Another possible locus of the age difference in discrimination of oblique lines is in memory. Children may not retain orientation information well, particularly information with respect to oblique lines. Thus, while a specific code such as 'vertical' or 'straight up and down' might be generated by the child for some stimuli, labels such as 'oblique' or 'diagonal to the left' may not be available to the child for others. Support for the memory hypothesis comes from a study by Bryant (1969) in which successive and simultaneous discrimination tasks were compared. In the former task, the standard stimulus appears before the test choices and is not in view at the time of the test; in the latter, the standard remains visible. Bryant (1969) found that the usual age differences appeared in the successive discrimination task: five year olds performed less well than seven year olds on the oblique discrimination. The one exception to this finding was that when the standard was an oblique and the discrimination to be made was between that oblique and a vertical or a horizontal, no age difference was observed. Furthermore, no age difference occurred in the simultaneous discrimination condition. The implication is that, while children retain some information indicating the presence of an oblique, they fail to differentially encode the direction of the oblique. When retention is eliminated, so is the age difference. However, Harris et al. (1974) found that five year olds could perform a successsive discrimination when the standard stimulus remained constant for all trials; they conclude that the five year old's memory for orientation is quite fragile.

Moreover, Jeffrey (1966) was able to train four year olds to discriminate between mirror image obliques. Training was carried out by having subjects respond to obliques to which arrowheads had been added;

the subject's response consisted of pushing a button on the side to which the arrowhead points. Thus a positive oblique would require a right button response, while the correct response for the negative oblique would be on the child's left. On test trials, regular oblique line stimuli were presented. Training on the arrows was found to increase performance relative to a group not receiving such training. It could be argued that the children were being shown a discriminative feature of oblique lines. It is also possible to sugest that the children were learning a motoric code for the two obliques.

In general, however, it is difficult to conceive of an encoding hypothesis as an explanation for the oblique effect. One doesn't think of an octopus as generating codes for orientation or of coding as playing a role in spatial acuity tasks. It is altogether possible that the studies supporting these two types of hypothesis are not really attacking the same problem at all. While it is convenient to explain both acuity and discrimination deficits in terms of a single oblique effect, as Appelle (1972) does, it may be a mistake to do so. Recall that Sutherland's octopus was totally unable to learn a discrimination between mirror image obliques. Human adults are able to learn such a discrimination; human three year olds are not. It seems likely that what is happening in these discrimination experiments is that human adults are able to offset the sensory deficit by generating an appropriate verbal code for the oblique lines, while children and octopi are not. Whether such a proposition is reasonable, however, is difficult to determine from many of the experiments previously described, as no attempt has been made to control the extent of processing occuring.

A more recent study (Holmes & Olsho, in preparation) was an attempt to deal with this problem. In all of the experiments described above the task employed can be characterized as having relatively long and uncontrolled stimulus processing time. This fact makes it difficult to distinguish the effects of perceptibility from those of encoding since both processes might be occurring during these long intervals. In the Holmes and Olsho study processing time was more closely controlled. In that experiment a line in one of four orientations (vertical, horizontal, 45^o positive and negative obliques) was presented to five year olds and adults. Stimuli appeared either on the left or right side of a CRT for 10 msec and were followed by masks at various intervals ranging from 10 to 100 msec. In one task subjects were asked to indicate the orientation of the line. In the other task subjects indicated the side of the screen in which the line had appeared. Preliminary analysis of the results showed that while five year olds do not perform as well as adults, they do not perform differentially worse on oblique lines, in either detections (left-right) or recognitions (orientation). In addition, though there were slightly more confusions made between the two oblique lines, the pattern of confusions is the same for the children and the adults. Thus, in this situation where processing time is controlled at a short duration, age differences are not found as a function of orientation.

One possible explanation for these results is that the relative lack of processing time served to circumvent age differences in encoding abilities. In other words, at short processing intervals, neither age group may find it necessary to generate anything but a visual representation of the stimulus to perform adequately.

The problem is one of determining the components of the system which are primarily involved in the Holmes and Olsho study. Keep in mind that what is referred to as encoding here represents all those processing stages beyond the sensory stage, which lead to the storage of information. It was assumed that by limiting processing time, only sensory processing would be required to perform the task. However, even if that assumption is true, it would be fallacious to conclude that there are not age differences in the sensory processing of different orientations. It might be concluded that children and adults can discriminate lines differing in orientation by 45°, but nothing can be said as to the relative sensitivity to changes in orientation at different positions. Since psychophysical data (Campbell & Kulikowski, 1966; Hirsch et al., 1974) indicate that tuning occurs within about 15° even for the less sensitive units, a task in which orientation differences on the order of 45° are used might mask any sensitivity differences between processing units for different orientations, as well as any age differences which might exist.

The present study, at any rate, was an attempt to distinguish between sensory and encoding mechanisms in a situation in which subjects were required to use orientation information. If an encoding hypothesis explains the difference between five year olds and adults in the standard discrimination experiment, then use of variously oriented lines in a situation in which encoding of orientation is not required should eliminate the age x orientation interaction observed in studies such as Rudel and Teuber (1963). The intent here was to create such a situation. On each trial a line in one of several orientations was presented to five year olds and adults. However, rather than having to identify the orientation of the line directly, subjects were asked to report to which of two colored lights the line was pointing. The interval between the offset of the line stimulus and the onset of the two colored lights was varied. In the case in which there was no delay in light onset encoding of orientation should not have been required. If on the other hand, the response choices were delayed by five seconds, some sort of encoding should have been necessary such that the usual age differences should have been found. Such a pattern of results would support the notion of two "oblique effects."

METHOD

Design. Four independent variables were manipulated in the present study. The stimulus lines appeared at orientations of 0°, 22° 30', 45°, 67° 30', 90°, 112° 30', 135° or 157° 30' relative to the horizontal, clockwise postive. The two lights between which the subject chose on each trial were spaced 11° 15', 22° 30', or 45° apart. In addition light onset occurred at either 500 msec (no delay) or 5500 msec (5 sec delay) following stimulus offset. Finally, two subject age groups were employed, five year olds and adults. The combination of three choice distances for eight orientations under two delay conditions for two age groups resulted in a 3 x 8 x 2 x 2 repeated measures design with subjects nested within age levels.

Subjects. Six subjects in each age group were used. Adult subjects were undergraduate or graduate students at Loyola University. Five year old subjects were located through the university child care center and through friends.

Stimuli. The stimuli were presented on a cathode ray tube (CRT) interfaced to a PDP/8E digital computer. (Mayzner, 1968; Mayzner et al., 1967). The display console used was a DEC VR-14 with a P24 phosphor and with a display luminance under steady state conditions of about 1 mL. A circular array of light emitting diodes (LEDs) fixed in a square of black plexiglass around a hole 6 cm in diameter, was centered 1 cm in front of the CRT screen so that the stimulus lines appeared along one of eight diameters of the circle (see Fig. 1). The 32 LEDs, eight each of four colors (red, orange, green and yellow) were evenly spaced around a circle

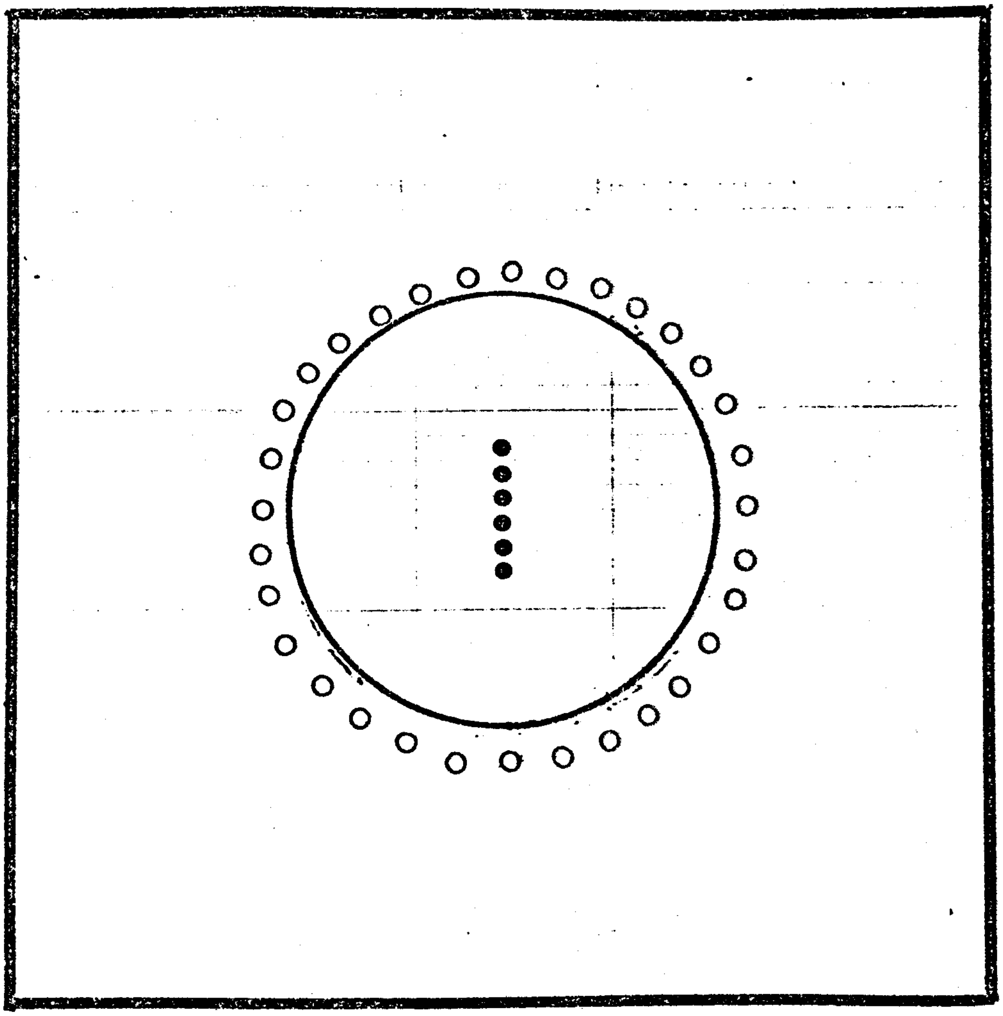

Fig. 1 Stimulus display; vertical line surrounded by thirty-two light emitting diodes.

making them 11° 15' of arc apart. This resulted in the placement of LEDs at each end of each stimulus line with additional LEDs midway between the adjacent line ends. A piece of rear projection screen fixed to the front of the plexiglass square prevented subjects from seeing the holes in which the LEDs were embedded. The colors of LEDs were arranged so that no LEDs of the same color were ever lit on the same trial. Each LED subtended 2' visual angle (va) with LEDs spaced 1.5' va apart. The target line actually appeared on the CRT screen and consisted of series of colinear luminous dots on a black background. Each stimulus line subtended 1° 48' va. Line orientations were presented in random order, each line appearing twelve times in each delay condition. Ninety-six trials were run for each delay condition, representing all combinations of eight orientations by two ends of each line by three choice distances by positive vs. negative distance (i.e., wrong alternative clockwise or counterclockwise from correct LED).

Apparatus. The PDP/8E digital computer mentioned above controlled both stimulus and LED presentation at the appropriate intervals. The orders of line and LED presentation were predetermined. The parameters designating line orientation were punched on paper tape and read on a trial-by-trial basis by the computer. Following a pause during which one experimenter selected the appropriate LEDs appropriate computer software resulted in the stimulus line appearing on the CRT display and the subsequent activation of the desired LEDs. Computer, tape reader, teletype and LED switch box were located in a room adjacent to the one containing the CRT and subject station; communication between the two rooms was accomplished via intercom.

The room containing the subject station was dimly lit, so that the subject or experimenter could record responses on an answer sheet. However, subjects viewed the stimulus array through a black viewing tube with eyepiece preventing the intrusion of light from the room into the subject's viewing area. Thus the subject had no cues as to the orientation of the stimulus line such as edges or contours. Moreover, as mentioned above, he could not see the LEDs when they were not lit. In addition, the eyepiece fit rather snugly around the subject's head, holding it steady and at the same position on each trial.

Procedure. Each subject was seated in the experimental room while the experimenter instructed him in the task. The no delay condition was always run first, since any practice effect would work against the predicted effect and pilot work indicated that five year olds became discouraged when immediately faced with the delay situation, leading them to adopt a strategy of guessing without regard to the stimulus presented. In both conditions the subject reported the color of the LED to which the line he had just seen was pointing: adults recorded their responses by marking an answer sheet; children responded verbally to the experimenter who remained with them throughout the experiment and who recorded their responses. In addition, the experimenter gave the five-year-old subjects a token for each correct response which could be used to buy a prize at the end of the experiment. On each trial two LEDs were lit, located either 11° 15', 22° 30' or 45° in arc apart. The light could appear at either end of the line on any given trial.

The experiment proper was preceded by a series of twelve practice trials chosen at random from the experimental trials. Any subject who was unable to perform the task, as indicated by a score of less than 50% correct on the practice trials was run through the series a second time. No subject scored below chance on this second series. Each trial was initiated by a signal from the subject and consisted of a fixation point, exposed for 750 msec, followed immediately by the target line, 20 msec in duration, followed by, after an interval of 500 or 5500 msec the onset of the two LEDs. The LEDs remained lit until the subject signalled for the next trial.

The experiment took approximately two hours to run: since trial presentation was controlled by the subject, the exact duration of the experiment varied with the subject's speed in responding. In general the five year olds took a little longer than the adults. The experiment was broken into four sessions of about 30 min. each covering 48 trials. A short break followed the first and third sessions, a somewhat longer break the second. In a few cases, half of the experiment was run on each of two days.

RESULTS

The outcome of the experiment is shown graphically in Fig. 2. As can be seen there, the possibility of ceiling and/or floor effects seemed to exist. Consequently, Hartley's F_{max} test for homogeneity of variance was performed and showed that there was no cause for concern over the homogeneity problem, with all F_{max}'s well below the critical level for $p=.05$. A repeated measures 3 x 8 x 2 x 2 analysis of variance with subjects nested in age groups was, therefore, performed. The main effects of age, delay condition, orientation and distance between LED alternatives were all found to be significant (see Table 1). In addition, the delay x orientation interaction had a significant effect. As indicated in Fig. 3, a delay in LED onset of five seconds led to a decrement in performance for the horizontal line and a group of lines orientated close to it (± 22° 30') but not for the vertical line and a similar group.

Further, significant age x choice distance and age x choice distance x orientation interactions were observed (Table 1). The age x choice distance interaction is apparently due to the fact that the five year olds appear to benefit little from an increase in the distance between choice lights, while adults do benefit consistently from each such increase (Fig. 4). This tendency does not hold up for all line orientations however; simple effects analyses of the age x distance interaction at each orientation showed that for three orientations, 22° 30', 90°, and 112° 30', both child and adult performance increases with the distance between LEDs. Thus, the age x distance x orientation interaction.

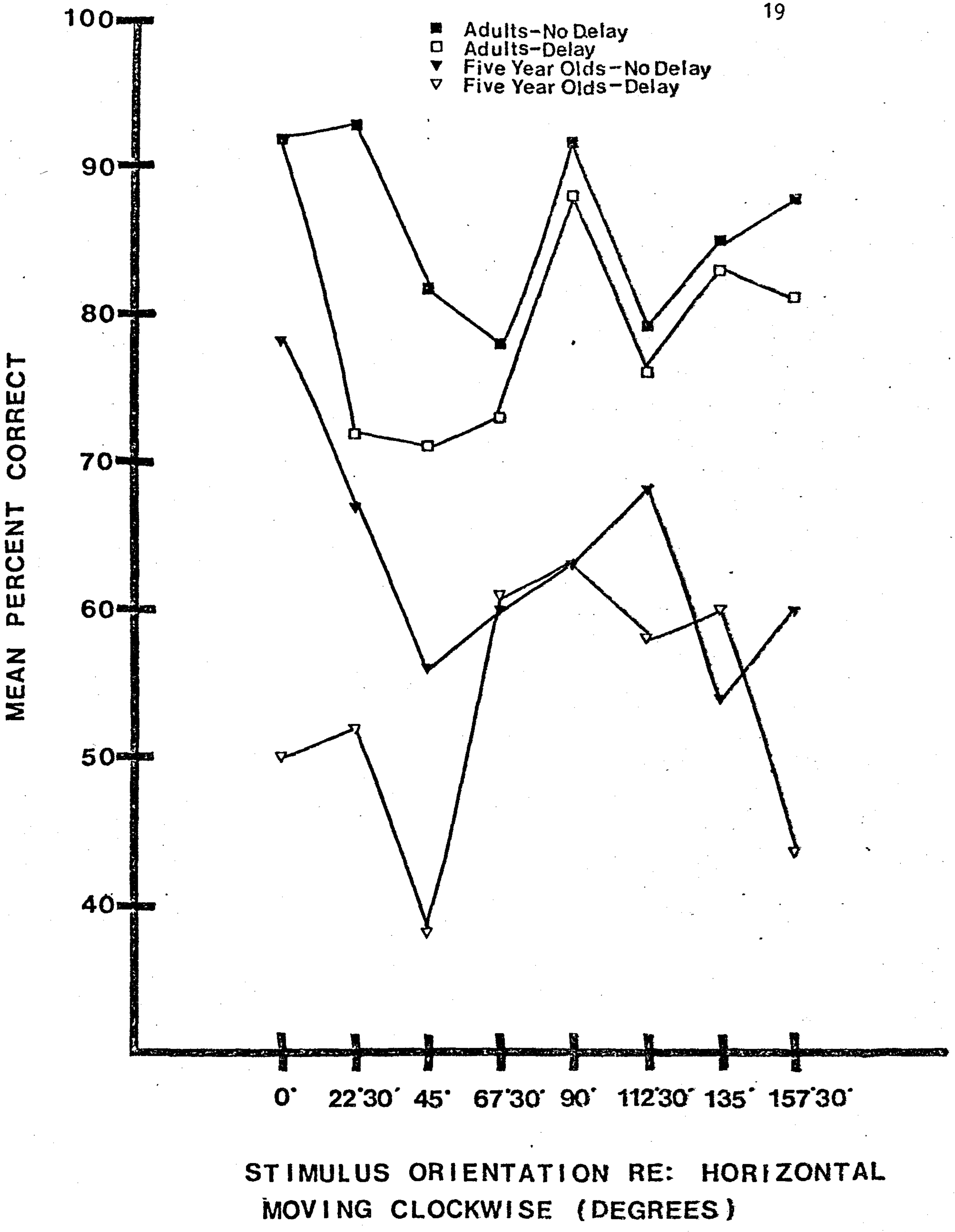

Fig. 2 Percent correct identifications as a function of stimulus orientation for children and adults under two delay conditions.

Table 1

Analysis of Variance

Source	SS	df	MS	F
Between Subjects	173.98	11		
Age (A)	145.00	1	145.00	50.04****
Subjects within age groups (S(A))	28.98	10		
Within subjects	474.32	564		
Delay (D)	15.02	1	15.02	7.24**
A X D	.77	1	.77	.37
D X S(A)	20.74	10	2.07	
Orientation (O)	18.50	7	2.64	3.14***
A X O	11.07	7	1.58	1.88*
O X S(A)	59.00	70	.84	
Choice distance (C)	17.98	2	8.99	16.20****
A X C	7.63	2	3.81	6.87***
C X S (A)	11.10	20	.55	
D X O	11.72	7	1.67	2.48**
A X D X O	8.25	7	1.18	1.74
D X O X S (A)	47.33	70	.68	
D X C	.07	2	.04	.06
A X D X C	2.26	2	1.13	1.85
D X C X S (A)	12.21	20	.61	
O X C	8.27	14	.59	1.07
A X O X C	20.34	14	1.45	2.64***
O X C X S (A)	77.00	140	.55	
D X O X C	9.23	14	.66	.84
A X D X O X C	6.10	14	.44	.56
D X O X C X S (A)	109.73	140	.78	
Total	648.30	575		

* $p<0.10$
** $p<0.05$
*** $p<0.01$
**** $p<0.001$

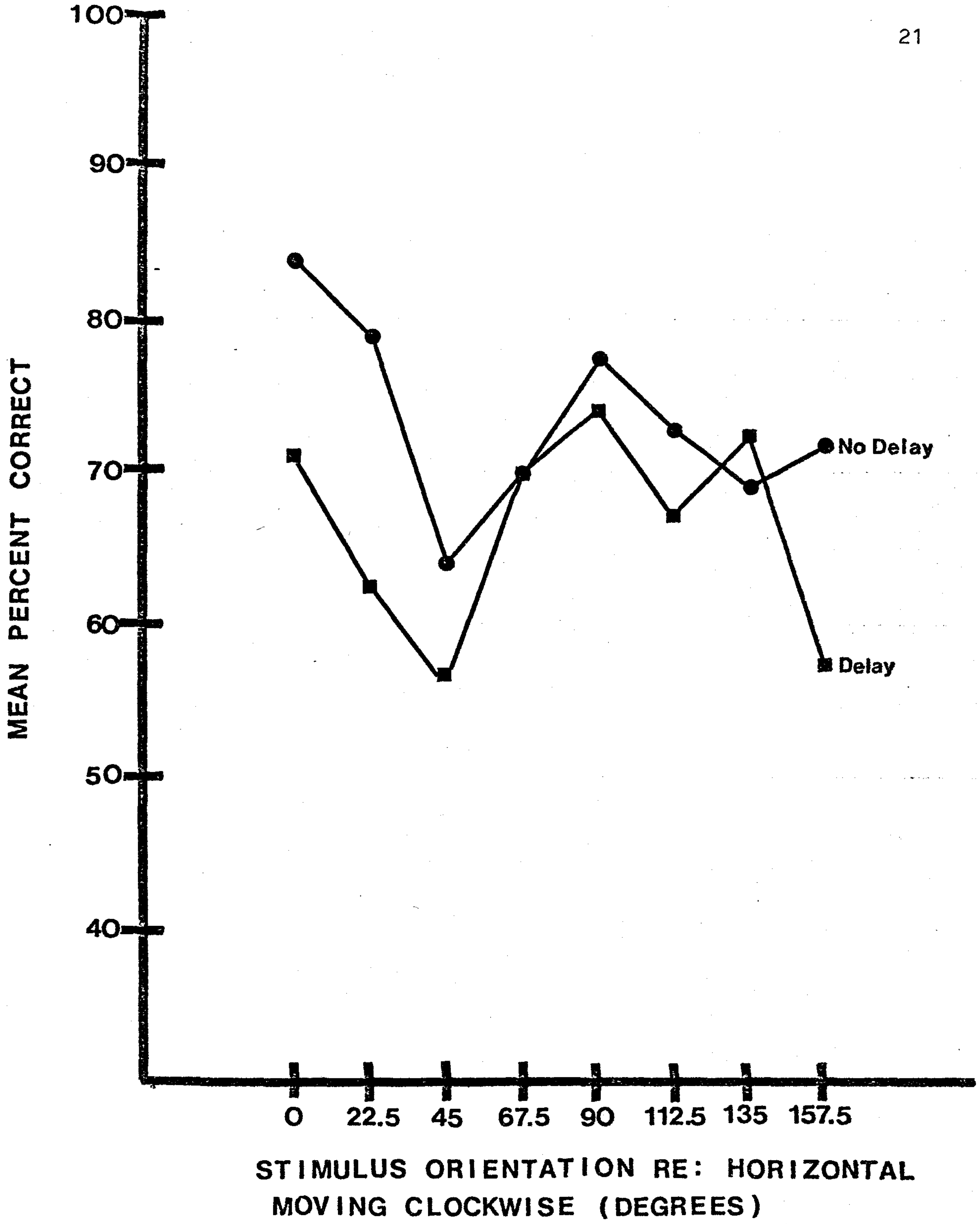

Fig. 3. Percent correct identifications as a function of stimulus orientation under two delay conditions.

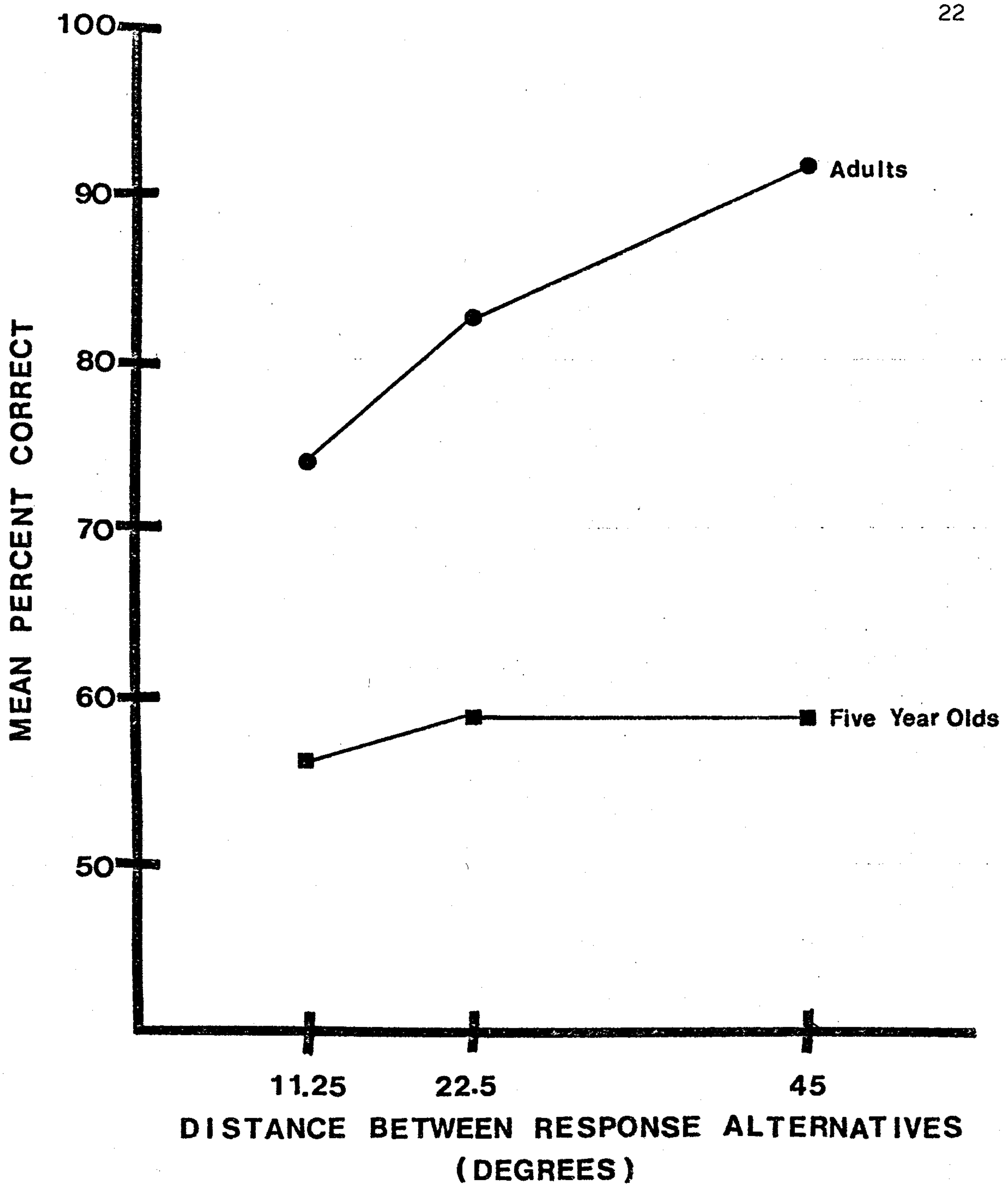

Fig. 4. Percent correct identifications as a function of distance between response alternatives for two age groups.

As the orientation main effect was of central concern, a number of other tests were performed on the orientation means. First of all, comparisons between all possible pairs of means by the Newman Keuls procedure revealed significant differences only between the vertical and the 45° oblique line, the horizontal and the 45° oblique line, and marginally, between the horizontal and the 157° 30' oblique line. (Table 2). As the age x orientation interaction was, however, just short of significance, the Newman Keuls was repeated for the age groups separately. For the adults (Table 3), significant pairwise differences were found only between the 45°, 67° 30' and 112° 30' obliques and the vertical and horizontal lines. The same analysis of the five year olds' data (Table 4) showed that performance on the 45° and 157° 30' oblique lines was significantly worse than that on all other lines, but no other differences were significant.

In Fig. 5 the data are recast as they might appear in a typical study of the oblique effect: the data for the horizontal and vertical lines (HV) combined are compared to the combined scores for the oblique lines (O). Simple planned comparisons between HV and O means in each age x delay cell confirmed the trends which seem apparent in Fig. 5. The difference between HV and O is significant for the adults under both delay conditions ($\underline{F}$ (1,70)=4.62, p.<05 for no delay; $\underline{F}$ (1,70)=8.92, p.<01 for delay condition), but only under the no delay condition for the five year olds ($\underline{F}$ (1,70)=4.18, p.< 05). This appears to be due to a floor effect for the children in the delay condition. As an examination of Fig. 5 reveals, the curves for the children and the adults in the no delay condition are parallel; that is, there is no age x orientation

Table 2

Newman Keuls Test on Orientation Means

(i)

Orientation		Mean
45°	(02)	2.49
157° 30'	(06)	2.64
67° 30'	(03)	2.76
112° 30'	(04)	2.82
22° 30'	(01)	2.83
135°	(05)	2.85
90°	(V)	3.00
0°	(H)	3.10

(ii) Differences between means and critical values.

	06	03	04	01	05	V	H	Critical value $(s_0 q_{.95}(r,60))$
02	.15	.27	.33	.34	.36	.51	.61	.48
06		.12	.18	.19	.21	.36	.46	.47
03			.06	.07	.09	.24	.34	.45
04				.01	.03	.18	.28	.43
01					.02	.17	.27	.37
V							.10	.31

(iii) Significant differences

	06	03	04	01	05	V	H
02						**	**
06							*
03							
04							
01							
05							
V							

** $p<.05$

* $p<.10$

Table 3

Newman Keuls Test on Orientation Means
Adults

(i)

Orientation	Mean
45° (02)	3.06
67° 30' (03)	3.06
112° 30' (04)	3.11
22° 30' (01)	3.31
135° (05)	3.36
157° 30' (06)	3.36
90° (V)	3.58
0° (H)	3.67

(ii) Differences between means and critical values.

	04	01	05, 06	V	H	Critical values $(s_0 q_{.95}(r,60))$
02, 03	.05	.25	.30	.52	.61	.47
04		.20	.25	.47	.56	.45
01			.05	.27	.36	.43
05, 06				.22	.31	.38
V					.09	.31

(iii) Significant differences

	04	01	05, 06	V	H
02, 03				*	*
04				*	*
01					
05, 06					
V					

* $p < .05$

Table 4

Newman Keuls Test on Orientation Means
Five Year Olds

(i)

Orientation		Mean
45°	(02)	1.91
157° 30'	(06)	1.91
135°	(05)	2.33
22° 30'	(01)	2.36
90°	(V)	2.41
67° 30'	(03)	2.47
112° 30'	(04)	2.53
0°	(H)	2.53

(ii) Differences between means and cirtical values.

	05	01	V	03	04,H	Critical values $(s_0 q_{.95}(r, 60))$
02, 06	.42	.45	.50	.56	.62	.47
05		.03	.08	.14	.20	.45
01			.05	.11	.17	.43
V				.06	.12	.40
03					.06	.34

(iii) Significant differences

	05	01	V	03	04, H
02, 06	*	*	*	*	*
05					
01					
V					
03					

* $p < .05$

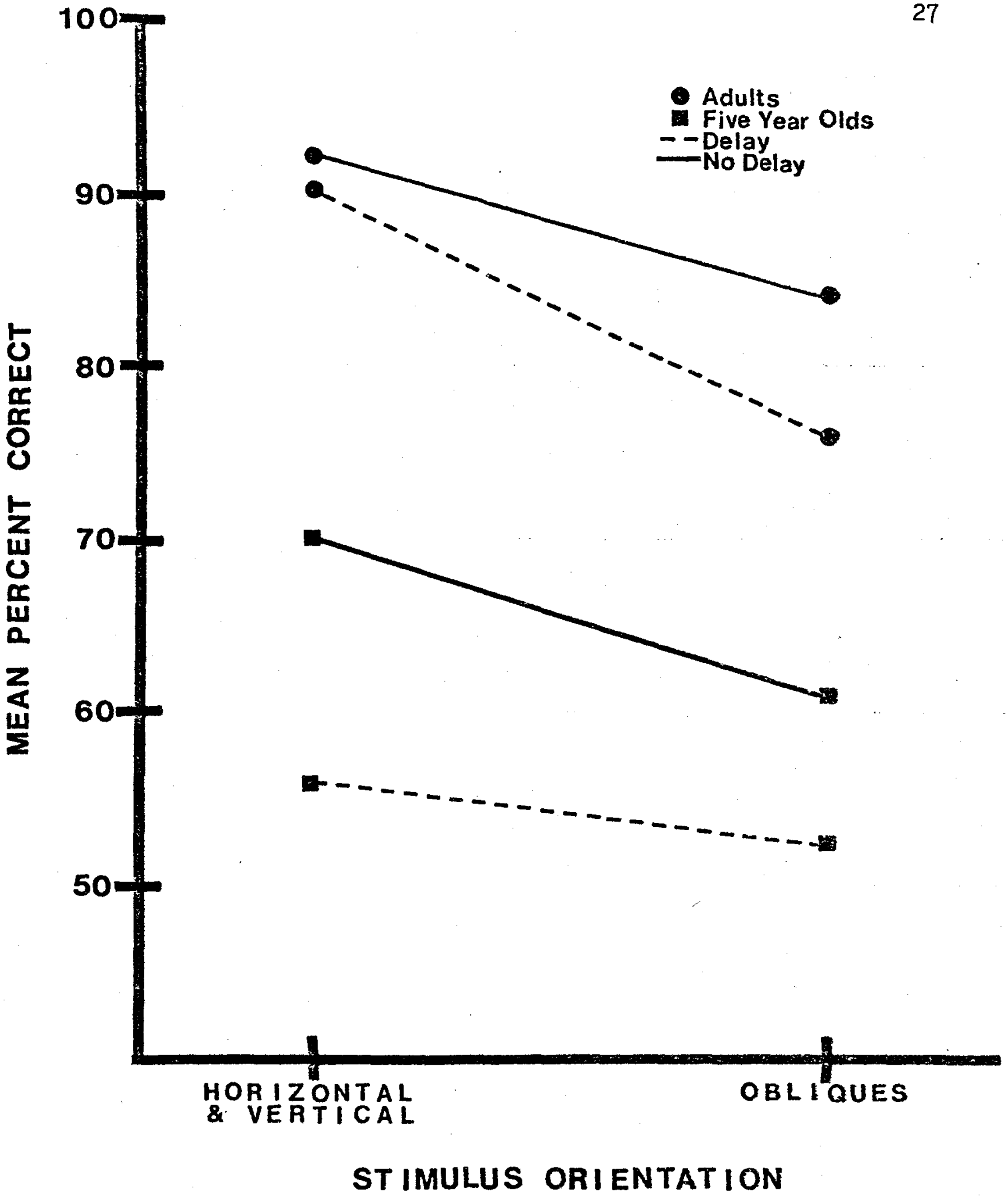

Fig. 5. Percent correct identifications for horizontal - vertical and oblique lines by two age groups under two delay conditions.

interaction in this condition. Thus, the developmental oblique effect is not present under the no delay condition.

In the delay condition, adult performance on all lines falls somewhat. However, the decline is appreciably greater for oblique lines. In the case of the five year olds, performance on both the HV and O falls to a near chance level. It would appear that the introduction of the five second delay makes encoding of orientation information for oblique lines more difficult for adults, but that the delay makes encoding of any orientation virtually impossible for the younger subject.

DISCUSSION

The present study was designed to answer two questions. First, are there differences between five year olds and adults in their sensory processing of oblique lines, relative to that of horizontal or vertical lines? Second, what is the nature of the previously observed developmental oblique effect? The answer to the first question seems apparent: whether the oblique lines are considered separately or together, the five year old's performance, though considerably poorer than that of the adult, is not qualitatively different from that of the adult when there is effectively no delay between stimulus offset and response. The implication is that the child's sensory apparatus is not qualitatively different from the adult's. Thus the commonly observed developmental oblique effect would not appear to be a sensory effect. In that aspect, the current study is a replication of the Holmes and Olsho study described above.

As to the hypothesis that the developmental oblique effect stems from the five year old's inability to generate appropriate codes for oblique lines, the results obtained here support the contention that the child does not use the same coding strategy as the adult does. To begin with, the orientation by delay interaction in the adult data (Fig. 5) indicates that oblique lines represent an encoding problem, even for the adults when information is to be retained for an appreciable length of time. However, for the five year olds, it is not the case that oblique encoding is the difficulty in the delay condition; in the situation employed here, they are completely unable to generate codes for any orientation. This follows from the failure to find a difference between the horizontal vertical pair and the obliques in the delay condition (Fig. 5). Recall, moreover, that there is no statistical evidence of a floor effect here. Further support for the idea that the five year olds are unable to encode appropriately in the delay condition comes from the age by choice distance interaction. The fact that the adult's performance improves with distance between response alternatives implies a certain degree of imprecision in his orientating codes. However, the young child totally fails to benefit from any increases in choice distance. This finding is predicted by the hypothesis that the child finds it impossible to encode orientation here: if the orientation information is not present in the child's memory, the choice of responses becomes irrelevant.

A question might be raised, though, as to why five year olds are able to encode horizontality and verticality in discrimination studies. Several possible explanations for this discrepancy exist. First, the rather brief stimulus duration used here may not have given the children sufficient time to generate a durable code for orientation. A second possibility might be that since most of the stimuli were difficult to encode obliques, the five year olds were discouraged from using verbal codes for any line, thus leaving them without an effective strategy for performing in the delay condition. Because these two explanations assume that the child has the capacity to encode orientation in the same manner as the adult, but is more vulnerable in the face of time constraints or motivational problems, either has the advantage of parsimony since it makes it unnecessary to posit different orientation processing mechanisms for the children and the adults. In addition, since the possibility of ceiling problems exists in at least one of the studies previously reporting the developmental oblique effect (Bryant, 1969), it is at least possible that no difference in encoding strategies exists between five year olds and adults. If this proves to be the case, then what has been referred to as the developmental oblique effect is not a developmental effect at all. The observations which led to the hypothesis of qualitative changes in encoding with age could be explained simply in terms of differences in overall performance level between the five year old and adult, which are present in a variety of situations not necessarily involving orientation processing.

On the other hand, a third possibility is more consistent with other evidence of the preschooler's inability to deal with abstractions (e.g. Piaget, 1953; Olson, 1970). Recall that in the present study no contours were present within the subject's visual field. It is possible, then, that the elimination of cues to orientation also eliminated the child's means of encoding orientation. Thus, the five year old's inability to retain orientation information in the delay condition is consistent with the notion that the preschooler uses concrete reference contours in the surround as a mechanism for encoding orientation. As oblique contours are less commonly found, the young child would have comparatively more difficulty with obliques than the adult, who is able to generate abstract codes in the absence of a concrete frame of reference. Further support for this hypothesis is found in the relative immunity of the vertical stimulus to response delay in both age groups.

One might predict that a subject would have a fairly strong sense of the vertical, even in the absence of visual reference contours, from his awareness of his body position relative to the direction of gravity. Thus, the vertical can be referenced with respect to vestibular as well as visual sensations. This is consistent with the findings of Berman et al. (1974) and Berman & Golab (1975) who found that children reproduced the vertical more accurately than the horizontal and the obliques when the test stimulus was presented against a circular background. But while the evidence supporting the hypothesis that the preschool child requires a concrete referent to encode orientation is strong, it remains for future research to eliminate the artifactual problems mentioned earlier before a definite statement can be made.

An incidentally interesting aspect of the results is the shape of the performance curves for all eight orientations (Fig. 2). Though most clearly seen in the adult data, it would seem that the greatest deficit in all conditions occurs for the 45° oblique line, the stimulus most frequently used in other studies. Oblique lines falling between this line and the vertical or horizontal lines in orientation seem to be of intermediate difficulty. One possible explanation for this finding is that the non-45° obliques are processed in terms of the vertical or horizontal orientations. Thus the 22° 30' oblique is distinguished by the fact that it is close to the horizontal. A parallel sensory explanation would be that the degree of uncertainty in the visual system is lower in the case of non-45° obliques, since the number of units firing in their presence is restricted by the fact that horizontal and vertical-sensitive to orientations as far as 22° 30' from a 45° stimulus might fire to some extent when a 45° line is presented. This would not be the case for an oblique falling within 22° 30' of the horizontal or vertical line. An alternative hypothesis is that the fineness of tuning of orientation processing channels decreases gradually as a function of distance from the horizontal and vertical lines. This might be expected if the locus of the oblique effect is at a retinal level as claimed by Rentschler and Fiorentini (1973).

Finally, a comment on the sensitivity of the paradigm employed here is in order. Recall that in earlier studies (e.g., Bryant, 1969) performance in all cells except that in the oblique comparison were at the ceiling. In this study, on the other hand, it was possible to show a deficit for the horizontal-vertical pair by introducing a five second delay; thus the sensory and encoding phases of processing are separable using this paradigm. Additionally, answers to the question of the role of memory and encoding in the processing of orientation might be obtained by varying the length of the delay between stimulus offset and the onset of the response alternatives. One problem which may exist, however, is that the results obtained here depend to some extent on the choice of stimuli; that is, it might be argued that the use of eight stimulus lines, as opposed, say to the usual four, resulted in greater confusability among the oblique lines. Although the subject in this situation chose between two alternatives on each trial, it is not possible to assess the effect of having used eight lines from the present data. Fortunately, however, it is possible to check for that possibility within the same paradigm.

At any rate, it is apparent that the locus of the developmental oblique effect is not in the child's sensory equipment; the findings reported here are also consistent with other evidence of the preschooler's inability to represent orientation in symbolic terms.

SUMMARY

Previous research has demonstrated that a variety of animals, including man, has difficulty in the visual processing of obliquely oriented lines, as opposed to horizontal or vertical ones. In addition, several studies have shown that the size of this oblique deficit in preschoolers is greater than that found in school age children and adults. In an effort to separate the sensory aspect of the oblique effect from the memory encoding problems believed to account for the latter "developmental" oblique effect, lines in one of eight orientations were presented for identification to five year olds and adults. Subjects identified the orientation of the line, however, by reporting the color of a light to which the line had been pointing. Two response alternatives were presented on each trial, 500 (no delay) or 5,500 (delay) msec. following the offset of the stimulus line. The results show an oblique deficit for both children and adults in the no delay condition, but no age x orientation interaction exists. In the delay condition, on the other hand, an age x orientation interaction is apparent. The data is interpreted as supporting the hypothesis that the "developmental" oblique effect is not a sensory effect and that age differences in orientation encoding strategies account for this effect.

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The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

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