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LESTER, Sylvia, 1948-
A DEVELOPMENTAL STUDY OF TEMPORAL ASPECTS IN THE PERCEPTION OF A KINETIC DEPTH PHENOMENON.

City University of New York,
Ph.D., 1977
Psychology, experimental

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1977

A DEVELOPMENTAL STUDY OF TEMPORAL ASPECTS IN THE PERCEPTION OF A KINETIC DEPTH PHENOMENON

by

SYLVIA LESTER

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy. The City University of New York.

1977

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

6/14/77
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Abstract

A DEVELOPMENTAL STUDY OF TEMPORAL ASPECTS IN THE
PERCEPTION OF A KINETIC DEPTH PHENOMENON

by

Sylvia Lester

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This study was designed to investigate the role of rate of change in determining how a given transformation is seen. A kinetic depth phenomenon was shown to 4-5 year olds, 8-9 year olds, 12-13 year olds and adults. The shadow of a square form, which oscillated back and forth over a 90° arc, was projected on a screen. The rate of oscillation could be varied from one cycle per minute to 15 cycles per minute (using a gearmotor with speeds of 1, 2, 3, 6, and 15 rpm). In Experiment I, 80 subjects were shown a sequence of the five presentation rates and their spontaneous percepts were recorded. These percepts fell into three event categories: a contraction and expansion, a rigid motion in depth, and some combination of expansion and rigid motion at the same time. To investigate the relative compellingness of the spontaneous percepts at the fastest and slowest rates, a countersuggestion inquiry was conducted. After the last (15 rpm) presentation in the sequence, alternatives to the subject's spontaneous description of what he saw were suggested, each of which could be accepted or rejected. The slowest

rate (1 rpm) was then presented again and alternatives to S's responses were countersuggested by E.

In most cases the percept of the shadow varied with rate and, as the rate of presentation increased, there was a unidirectionality of the shifts in percept, from expansion to rigid motion. At slow rates of presentation there were age differences in the kind of event seen. Young children are more prone than older subjects to see the transformation as an expansion when it occurs slowly. Older subjects see rotation at slower rates of change than younger subjects who begin to see the shadow as a rigid motion event only at fast rates. Subjects of all ages saw the transformation as a rigid motion event at the faster rates of presentation.

A second part of the study controlled for two aspects of the sequential presentation in Experiment I, and dealt with the question of whether immediately previous experience would account for the shifts in percept that were found in Experiment I from expansion (at slow rates) to rigid motion (at fast rates). In Experiment IIA, 40 different subjects (in four age groups, as mentioned above) were shown a slow/slow/slow condition: a repetition of three presentations, all at the slowest rate (1 rpm). In Experiment IIB (using still a different sample of 40 subjects) a slow/fast/slow sequence of rates were shown. Both conditions of Experiment II focussed on differences between responses to the first and last "slow" presentation in terms of whether expansion, rigid motion, or some combination of these was seen. From the results of Experiment II, it was clear that neither seeing the transformation again and again, nor having seen the transformation as

a rigid motion (in the intervening "fast" presentation in IIB) accounted for the shift toward seeing a rigid motion percept that was found in Experiment I. The influence of "learning" from repetition or "being shown" an intervening rigid motion event was minimal and did not account for the rigid motion responses in Experiment I. Instead it was the increasing rate of presentation that accounted for the same transformation being seen differently, as a rigid motion.

The study suggests that the same (geometrically-speaking) transformation that specifies a rigid motion may be seen as a rigid or nonrigid motion event, depending on its rate of change. This rate-dependency in event perception is especially evident among young children. Implications of this developmental difference for a theory of event perception are discussed.

ACKNOWLEDGEMENTS

This dissertation came to fruition through the assistance, patience, efforts, and participation of many people to whom I am deeply grateful. In particular, I would like to express special thanks to:

Dr. Joseph Glick who played the important role of chief mentor, personal translator, and was a veritable wellspring of subtle ideas.

Dr. Gilbert Voyat who guided me over the years through several research projects following a path of thought that led to this study.

Dr. Bill Mace for his helpfulness in conceptualizing the problem.

Dr. Louis Gerstman for his generous contribution of time, moral support, and statistical expertise in the data analysis.

Pat Greene and Rebecca Strauss of The Bank Street School for Children for allowing me to conduct the study in their school and for being so extraordinarily helpful and facilitating throughout. My thanks also to the teachers and staff, the pupils and the graduate students of Bank Street for their participation and enthusiasm.

Kathryn Weill Goldfrank, my cousin, whose help in running the experiment was invaluable and whose company was a great pleasure.

Gabriel Gabella who raised high the roof beams as carpenter and designer of the apparatus and who endured me with patience and succor.

Gloria Davis who provided support and feedback, and real camaraderie.

Andrew de Sciora and David Shaw for their help in solving the mechanical puzzles.

Michael Shectman and John Tagler for their efficiency and good humor in the final throes of realizing the typed product.

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CHAPTER I: INTRODUCTION

INTRODUCTION

The interest of this study has been to explore the extent to which rate of change specifies the kind of change or event we see. An event can be defined as a perceptual "unit" or an organization of what we see that involves both a change that takes place over time and a sameness that continues (Shaw, 1974a, p. 24). If we slow down or speed up the rate of change, this might alter what constitutes the perceptual unit we see, and so we might see a different event. We are suggesting that part of what defines or determines the particular event, the kind of change we see happening, is the rate at which the change takes place. Specifically, this study set out to explore what rate-of-change might have to do with the capacity of observers of different ages to distinguish between changes in position and changes in form.

J. Gibson claims that events (rather than "things") are the primary realities and are the "stuff" we perceive (J. Gibson, in preparation, p. 11). A particular event is specified by a particular kind of change in the light array. The changes in the surfaces of our environment, then, specify the events we see. He describes the three kinds of changes we see as "changes of layout" (an alteration of the shape of the surfaces of the environment) "...changes of color and texture...and changes in the existence of a surface" (caused change of state of the substance) (Gibson, in preparation, p. 3 & 4). The pertinent question, according to Gibson, is "What information is available in the light by means of which events can be perceived?" (Gibson, in preparation, p. 14). That is, what is the visual information

in the changing light array that specifies one event or another?

Shaw has described an "event" as having two kinds of information: The transformational invariant is the information that specifies the style of change an object undergoes in an event. The structural invariant is what doesn't change over the event and is the information about the identity of the object (Shaw, 1974a, p. 24).

This information about sameness and change has been studied in terms of its geometric properties (Gibson, 1957; Carpenter, 1974; Farber, 1972; Hay, 1966; Johansson, 1964; Braunstein, 1968) and in terms of relative rates of change (Graham, 1968; Johansson, 1964) but little attention has been paid to the "absolute" rate of change of the visual information.

We know from everyday changes that some motion occurs too slowly for us to notice: we cannot see the slow motion of the hour hand of a clock, for example, although we do notice the movement of the second hand. When films are shown in slow motion, on the other hand, we often notice changes that have taken place too quickly for us to see ordinarily. Events in which changes in position (motion) occur more slowly (the opening of a flower) or more quickly (the Auersperg effect of a rotating square, Piaget, 1969) than we can notice are often seen as changes of form or structure rather than as movement or change in position, and are therefore seen as entirely different kinds of events.

These examples show that the specification of an event by an environmental change when considered from the point of view of a perceiver, is rate dependent. A possibility explored by this study is that there may be developmental changes in this rate dependency.

E. Gibson, dealing with developmental issues has been led to discuss developmental changes in ability to detect event-specifying environmental changes. In earlier work (Gibson & Gibson, 1955) these developmental changes were discussed in terms of the differentiation of relevant classes of environmental change. In more recent work (E. Gibson, 1969) there has been theoretical focus on the ability to integrate information over time.

> The importance of event perception for perceptual development can hardly be overestimated....To perceive an event, some unity has to be detected over a temporal sequence of stimulation....To what extent learning is involved in the perception of simple events such as an object approaching and more complex ones...is a challenging question.
> (E. Gibson, 1969, p. 16)

> Does an infant have to learn to integrate over time to perceive an event? Does it perhaps detect only very short happenings at first and gradually develop so as to take in longer event sequences? We know too little about the perception of dynamic aspects of the world (especially how it develops) but these are interesting questions. Perhaps the infant detects some invariants over time from the outset.
> (E. Gibson, 1969, p. 381)

The perception of a series of changed stimulus states as a transformation rather than as a mere succession of different states is one of the central issues involved in the developmental application of the Gibsons' approach. It may be the case that some development of the temporal integration abilities of the young child may be a necessary feature of the increasing ability to differentiate classes of stimulus transformation. Some stimulus transformations may not be seen as transformations simply because they exceed the child's

ability to detect the relation of successively encountered stimulus states. Or, in keeping with E. Gibson's notions, transformations may not be differentiated because the unit over which temporal processing occurs changes with age. If either of the above occurs with development one would expect that rate changes in stimulus flow would have impact on the detection of environmental events. Slow stimulus transformations would provide less information about the environment for an organism which had a temporally limited ability to detect information.

In the present study, a "simple" event was used to explore to what extent varying the rate at which stimulus changes take place affects what event is perceived by subjects of different ages. Our interest in this study has been whether through the course of development the perceptual system might be getting better and better at picking up structure over slower, more extended (although not necessarily more complex) sequences of stimulation. Might children seeing an event at "slower-than-usual" rates show greater differentiation or less capacity to integrate than adults? If varying the rate of change of an event, so it is greatly slowed down, affects which transformational and structural invariants can be picked up, it was expected that the information picked up, under different rate conditions by young children (as compared to older subjects) might also vary.

The idea that rate of change may affect what transformational and structural invariants are detected, also implies that a "simple" event, which does not normally seem to include an extended sequence of happenings, may in fact, when considerably slowed-down, seem like a much more complex event sequence.

We have chosen to study these issues with respect to the "kinetic depth effect" paradigm. Wallach and O'Connell (1953) constructed a situation where a three dimensional object was back-lighted and its shadow projected on a two dimensional surface. This situation removes the classic cues to depth (motion parallax, binocular disparity, convergence, linear perspective, light and shade, texture gradients, etc.) leaving only information we get from transformations over time of the projected patterns. Most observers are able to report that they in fact see an object moving in depth. While a number of patterns have been used to generate these sorts of effects (e.g., shadows of flat or three dimensional objects, shadows of textured surfaces without contours, Von Fieandt and Gibson, 1959, and animated or computer generated films of outlines or dots, Johansson, 1975; Green, 1961; Braunstein, 1962b) the basic phenomenon of the perception of three dimensional movement from certain sorts of two dimensional transformations over time has been generally found.

As will be seen from a review of the literature presented below, the kinetic depth effect situation seems an opportune one in which to study the child's developing abilities to detect stimulus transformations as a function of rate of change, and to explore different notions of the development of perceptual abilities.

Past Research on the Kinetic Depth Effect

Perception researchers (and philosophers too) have long been asking how it is that we perceive depth and three dimensionality. The question stems from the fact that visual information comes to us through two dimensional retinal images, and yet we see the world as three dimensional

even when we use only one eye. The idea here is that depth is derived from an initial impression of a flat image. Locke, Berkeley and Helmholtz thought this derivation was the work of "quick actions of the mind" (Locke, 1894, p. 188-189), based on adding up cues and past associations between vision and touch. The Gestaltists claimed there are "rules of spontaneous organization" according to which retinal images of three dimensional forms produce depth experience and retinal images of flat forms lead to a visual experience of something flat. The classical cues for depth have been explored: motion parallax, binocular disparity, convergence, linear perspective, interposition, relative size, light and shade, etc. The idea of a "cue" presupposes a process to "interpret" or "infer" from the "cues" in a flat retinal image. J. Gibson (1950), instead, claims that it is the relative changes, the differences and transformations that are themselves the stimuli for perception, not the retinal image. He emphasizes the richness of velocity and texture gradients as higher order, relational information about depth. Then, it is not necessary to posit a mental process to organize optical elements, interpret cues or form associations to "convert" a flat retinal image into a percept of depth.

Metzger (1934) discovered the shadow phenomenon described above that Wallach and O'Connell (1953) later named "the kinetic depth effect." This was something comparable to a retinal image, a flat pattern, but depleted of all the texture, shading, interposition, etc. cues for depth, shape and orientation - all, except motion, and still it was perceived as having depth. How, under the circumstances of the shadow phenomenon, could an observer tell the difference between a change of position and a change of form?

Research on Stimulus Aspects: What Must Happen in the Projection Plane for Us to See Motion in Depth?

Wallach and O'Connell studied the moving shadow projections of several forms and concluded that with movement of either the subject or the object, the contours of an object must change in their length and direction simultaneously, or else a plane distortion will be seen rather than a rigid motion in depth (Wallach & O'Connell, 1953, p. 217). White and Meuser (1960) found that simultaneous change in length and direction were not always necessary for the perception of rigid motion in depth. Gibson and Von Fieandt (1959) showed patterns with no contours at all and found that observers could discriminate between elastic, nonrigid motions and the rigid motion of a surface swinging on a vertical axis. They concluded that continuous perspective transformations and "rubbery" transformations are two separate kinds of stimulus for vision. Farber (1972) used Gibson's shadow-caster but varied the distance between the object casting the shadow and the light source, thus exploring the effects of magnification and minification. He concluded that angular magnification leads to perception of distortion and change of shape as well as rotation in depth. Since the magnified sequences were judged to be nonrigid, Farber concluded that the perception of rigid motion depends on the metric relation within the sequences of perspective transformations. Gibson and Gibson (1957) projected shadows of a plane surface, a pattern, or texture (regular and irregular). All observers saw a constant shape turning and changing slant (none saw only compression of a flat two dimensional pattern). Gibson concluded that "any regular transformation of a bidimensional image tends to yield a tridimensional motion in

perception and the kind of transformation perceived depends on the kind of transformation the image undergoes" (Gibson, 1953, p. 311). In particular, "any continuous sequence of perspective transformations is the correlate of perceptually rigid motion" (Gibson and Gibson, 1957, p. 129). Clearly underlying this approach is the concept that it is not "cues" but families of transformations, relations between a family or sequence of forms, that is the stimulus for an eye. (Whether the transformation is actually or only apparently continuous is besides the point for Gibson; in either case, the information specifying rigid motion is "given" by the stimulus.)

> The eyes of animals and men are very good at detecting motions, perhaps they are just as good at discriminating types of motions. It might be that the one group of continuous transformations, the perspectives of rigid objects, constitutes one kind of stimulus for vision and that the other group, the "rubbery" transformations constitutes another kind of stimulus for vision.
> (Von Fieandt and Gibson, 1959, p. 345)

The idea is that a given transformation of the light array corresponds uniquely to a given kind of motion or change.

Shaw (1974b) showed that if the positions of a rotating cube are illuminated by a strobe light out of order, and we see a sequence of positions that do not naturally follow one another in the course of turning, we cannot make sense of the shape of the object and do not see a rigid cube in motion.

The Gibsonian position, is, then, that the retinal mosaic is sensitive directly to those transformations that inform us about the constant and changing properties of things. Hay (1966) used matrix

algebra to analyze the motions in the optic array that corresponded to objects moving in three dimensions. He concluded that for a visual response to be specific to a particular object and therefore veridical, it had to be determined by all the parameters of projected image transformation: translation, stretching, shearing, and foreshortening along both axes of the frontal plane. This seemed to demonstrate that it is the two dimensional transformations of the retinal image that specify objective features about object displacements in the third dimension.

Johansson (1964) found that the proportionally slowest rate of change relative to the origin was the determinant of what kind of motion in depth will be perceived (a looming or vertical or horizontal slanting), but that "any combination in the X and Y directions has a strong tendency to generate a perception of motion in depth" (Johansson, 1964, p. 199). Braunstein (1966, 1968) also found evidence that velocity gradients were important determinants of the depth perception of slanted surfaces. Graham measured differential angular velocity thresholds among adults using a rotating wire cube. When the differences between the rate of movement of one angle, as compared with another angle of the same cube, was below threshold, no rotation was seen (Graham, 1968).

Graham's research explored one aspect of thresholds of rate-of-change, but this was in terms of differential angular velocity (in seconds of arc per second) when the rate of movement of one angle of a rotating wire cube, for example, is compared with the rate of movement of another angle of the same cube. His point was that "kinetic movement differences are seen because of temporal variations

[within] a monocularly viewed image" (Graham, 1968, p. 20). He concluded that "small differences in angular velocity may be discriminated" (Graham, 1968, p. 19). Graham measured differential angular velocity thresholds (among adults) by having a subject adjust the depth of a vertical needle so that it was aligned with another fixed needle above it, while the whole display moved at a constant rate in the frontal parallel plane. Along the horizontal axis of the frontal plane, under "optimum conditions," the differential velocity threshold was one minute of arc per second. An interesting element in Graham's findings, in terms of the present study, was that "optimum conditions" included optimum velocity of the display's movement (although it is not clear what that optimum velocity was, it is also improbable that it would be directly comparable to any rate thresholds to emerge from the present study which uses an entirely different visual phenomenon, and studies a different set of events).

Graham also conducted an experiment with "real" as opposed to "differential" movement. It dealt with single visual stimuli moving at a constant rate. Here he found bigger objects must go faster to be seen as moving; the velocity threshold for seeing movement decreases with the addition of stationary reference marks or with increased brightness of the background (Graham, 1968, p. 23).

Graham, then, was defining the components involved in being able to see movement; that these "thresholds" are relative to many physical aspects of a given visual context. Graham was interested only in having adult subjects specify whether they did or did not see movement and he <u>explicitly</u> avoided discussing what he called the "new" phenomena seen when an object, described one way when stationary, is

described differently when it moves (Graham, 1968, p. 19). Graham also explicitly laid aside considerations of the "new phenomena" that concern the present study: that a stimulus seen to move, is described in one way at one rate of movement and differently at another rate of movement.

Research on "Processing": Do We Need to Process, "Decode" or Remember Visual Information to See Motion in Depth?

Researchers to be discussed here have worked under the assumption that our perception of depth through motion is neither "automatically triggered" nor directly specified by the information the eye receives from certain transformations in the projection plane. Instead, these researchers claim that this information needs to be processed or operated upon, if only by a "preference" (Johansson, 1975) or "heuristic" (Braunstein, 1976) to lead to accurate perceptions of depth. Wallach, O'Connell and Neisser claimed "it is necessary to ascribe to a memory trace (icon) the power to determine the organization of a visual form process" (Wallach, O'Connell and Neisser, 1953, p. 364). Gibson (Gibson, 1968, p. 344), states that depth perception is based on formless invariants so that it is neither the transformation, nor a particular set of forms per se that produce a depth percept, but the way the transformations interact with the forms.

Shepard and Judd (1976) studied the visual experience of intermediate positions and apparent movement when only extreme positions of a rotation in depth were presented. If the necessary time was not allowed between the presentations of the extreme positions, the subject saw distortions both in shape and movement. Shepard and Judd posited a "holistic perceptual imagery" (an internally constructed representation

of something three dimensional) which occurs over time; longer time was necessary between positions separated by a greater angle of rotation (Shepard and Judd, 1976, p. 954).

Shepard and Judd's work points to a rate property of the visual processing system: if greater angles of rotation require longer processing time, it might be that there is a "preferred," "normal" or maximal rate for visual processing. When looked at in terms of the stimulus change taking place, then, there are certain temporal conditions under which all the information for a smooth motion in depth seem to be specified; under different temporal conditions subjects have a different visual experience.

Braunstein showed that when presented discrete position changes between two separated dots, observers experienced visually a third intermediate position to complete a continuous path of movement. So that, he concluded, it is not necessary to remember anything (as claimed by Wallach, O'Connell and Neisser, 1953; Bower, 1967; and Peterson, 1974) but that we complete continuous transformations even when they are not shown (Braunstein, 1966, p. 688). It is, as Gibson would agree, not the positions but the transformations themselves that are important. However, Braunstein posits heuristic processes, decision rules (much as in problem solving) which are applied to visual information to speed up processing and to handle "degraded," incomplete visual information. An example of such a rule "produces judgements that a side of a quadrilateral is approaching when the angles that include that side decrease and, conversely, that a side is receding when the contour angles increase" (Braunstein, 1976, p. 167).

Johansson worked with computer-generated films of luminous dots or deforming outlines of geometrical figures. For example, a square which changed its shape slightly was seen by observers as a flexible surface with one corner bending. So figural change was always interpreted as being a continuous perspective projection of an object of constant shape and size, even if this meant inferring quite complex motions. Johansson posited a "perceptual tendency" to see rigidity and constancy of shape: "the visual system automatically prefers invariance of figure size, obtained by inferring motion in three dimensional space" (Johansson, 1975, p. 86). The visual system analyzes the proximal stimulus according to "decoding principles" that work in a "blind, mechanical way" according the projective geometry of central perspective. Johansson's idea (similar to Braunstein's) is that we <u>abstract</u> from the optical information, according to such "decoding principles" as "the principle of primary three dimensionality." Therefore, "any combination of changes in X and Y directions tends to generate a motion in depth" (Johansson, 1964, p. 199).

Piaget does not believe that the stimulus or visual information alone specifies the percept. He stresses the role of the activity of looking.

> The notion of perceptual equilibrium suggested by the facts is not that of a physical field with an exact and automatic balance of forces present, but rather of an active compensation brought about by the subject...it is in this context of active structuring that exchanges between subject and object take place...objectivity is constructed on the basis of and in proportion to the activities of the subject ....In the end, the relative adequacy of any perception to any object depends on a constructive process, and not on an immediate contact.
>
> (Piaget, 1969, p. 364-5)

Piaget points out the importance of perceptual "structuring" activities, moving the gaze and "adjusting shifting centrations" (Piaget, 1969, p. 248) in gathering visual information. (These are just the activities he claims children have difficulty with.) "Like problem solving, he explores, first choosing the points of centration, then relates objects to their contexts, transports, anticipates, and so on" (Piaget, 1969, p. 363). It is important that an observer decenter himself by means of this systematic activity, in order to correct deformations that come from the initial centrations. In this process of information gathering, perceptual activities are guided by notions of spatial transformations: "Where perception requires perceptual activity, we see only what we think of looking for" (Piaget, 1969, p. 349). Piaget also points to a process of decoding and integrating the visual information, once gathered: "Perceptual messages are transmitted in a figurative form that are decoded by being integrated into the system of transformations" (Piaget, 1969, p. 359). So, according to this view, both the picking-up (knowing where to look) and the decoding of perceptual information is limited by and dependent on the development of cognitive structures.

Perceiving the changing two dimensional shadow as a rigid motion in depth, like all perception of motion, according to Piaget (Piaget, 1969, p. 354) would involve these "structuring" and "decoding" activities. We might speculate that Piaget would perhaps find the kinetic depth phenomenon an especially good example of how perception provides us with changes in configurations and states only, unless notions of 'groups' of spatial transformations (here, in particular, perspective

transformations) intervene to subordinate the changes in configuration to the transformations (Piaget, 1969, p. 355). This would perhaps suggest that preoperational children who are "bound to states and configurations" (Piaget, 1969, p. 248) would not be prone to the kinetic depth effect and, more generally, that changes in perception would be related to changes in cognitive structures of spatial representations.[1]

According to E. Gibson, the progress of perceptual development consists in learning to distinguish in each situation those variables which are critical from those which are not, and to select and respond to only the former. Turvey (1977) points out that if a "discrete sampling" process were going on (something like Piaget's idea of "active compensation" and, later, "decentration") an observer would have to know in advance what category of object or event he was looking at, even before he had seen it, in order to "know" which invariants to look _for_. This is in fact the basis for Vurpillot's criticism (Vurpillot, 1976, p. 191) of the Gibsons' theory. Turvey however disputes the idea that visual information is picked up by means of any process of "discrete sampling." Not unlike Piaget's idea of preinferences, Neisser's recent idea that "anticipatory schemata" direct active search and create a "readiness" that determines what information

---

[1] However, Piaget, always considering perception as a problem-solving process involving "active compensation" on the part of the observer, admits to the capacity of preoperational children to make what he calls "perceptual pre-inferences" about events, even though they cannot make "logically governed" operational inferences on the basis of visual information. "The most elementary perceptual preinferences are probably those which intervene in threshold judgements, when the subject has to 'decide' or discriminate between effects due to the external stimulus and those which are due to 'noise' accompanying it." (Piaget, 1969, p. 307)

will be picked up next (Neisser, 1976), does not imply that these expectations "control" what we see. Perception is veridical and we do pick up unanticipated information which, according to Neisser, begins a cycle of searching for information in order "to embed what was picked up in some degree of context," (Neisser, 1976, p. 23). Here Neisser is clearly attributing some role to "information-already-acquired" and to a process of a cognitive sort.

The debate, then, as to whether there are processing requirements for perception continues. However, whether we consider the differentiation of critical stimulus invariants as the achievement of perceptual development, or whether we consider any of the more cognitive "processes" discussed above to be involved, either of these explanations accord importance to developmental changes: young children have somewhat different perceptual capabilities than adults. If we consider the specific and critical area of the perception of depth through motion (as in the kinetic depth effect), one might expect to find developmental differences here too. In fact, there is some experimental evidence that children <u>are</u> less likely than adults to see depth or rigid motion events from kinetic depth displays.

Johansson's research, as described earlier, seemed to indicate that the few 10 and 11 year olds, unlike the adults in his sample, saw the two dimensional alternative as often as the three dimensional alternative and that they often saw both simultaneously. He asked, then, whether there might be "an ontogenetic development of perception of motion and form changes" (Johansson, 1964, p. 192). Could it be that Johansson's "principle of three dimensionality" (a tendency to

interpret motion as being of a rigid structure moving in depth) is something achieved as a function of development?

Using a type of kinetic depth display, Carpenter also attempted to identify the nature "of the developmental function of motion as a mediator of perceived depth" (Carpenter, 1974, p. i). He found that his 6 year old subjects were unable to judge the changing orientations of rows of dots as they "rotated" in depth and he suggested as a possible explanation that they may, indeed, have failed to see any depth in the displays to begin with (Carpenter, 1974, p. 67).

If these studies can be seen to point to developmental differences in the perception of kinetic depth displays, to what might we attribute these differences?

Bower's work (1967) represents an intermediate position between theories of perception that focus on stimulus properties and those which give weight to the observer's "processing" and more cognitive capacities. Based on his research in infants' perception, Bower posited the importance of temporal factors of the stimulus and of the "processing mechanism." Bower, in his discussion of object permanence, has suggested that the perceptual systems of infants "have a rather low temporal resolution" (Bower, 1967, p. 415) and he claims this is attributable to two factors. First, the processing rate: when spatial transformations happen too fast, the change is seen as instantaneous and the kind of change cannot be registered. The second factor Bower suggests is the duration of the memory trace which in infants is brief so that the search for connectedness or continuity with an earlier percept is shortlived. Vurpillot, like Bower, has also pointed out the bi-directional developmental limitations on

perceptual processing, that the duration of a visual fixation decreases with age as the capacity to register the same amount of information in less time increases. This implies that "the young child can process only a relatively limited amount of information at a time, and it takes him a relatively long time to do that. Moreover, the information which can be combined or organized must be close together in space and time" (Vurpillot, 1976, p. 322).

Considering, now, the situation of young children watching a "simple" event, such as a kinetic depth display. Do children need to process, remember and integrate the visual information, or are those processing demands diminished if the information is already "close together in space and time"? Could it be that all the information specifying a rigid motion event is "given" when the transformation occurs at one rate, but not at another, considerably slower, rate?

Following this line of thought, it may be the case that differences in the rate at which a spatial transformation occurs, just as when we shift the geometrical properties of the transformation (Farber, 1972), might require the detection of new invariants..."...things look different and feel different as this occurs because the effective stimulation to which the person is now responding is different" (E. Gibson, 1967, p. 213). If so, it would seem that changing the rate-of-change involved in a transformation, even though the geometrical aspects and relative velocity of the transformation remain constant, may mean that this new rate of information flow corresponds to a different "perceptual unit" which specifies a different event.

This idea about what Graham (1968) called "new phenomena," that

the same sequence of transformations can look to us like an altogether different event, would seem to have to do with what changes in time are "seen together": what is it, then, that determines the "unit episode"?

> The flow of ecological events consists of natural units that are "nested" within one another. There are episodes within episodes, subordinate ones and superordinate ones. What we take to be a unitary episode is therefore a matter of choice and depends on the beginning and the end that are appropriate and not on the units of measurement. The number of episodes in a sequence cannot be counted unless the unit episode has been decided upon. Episodes, like surfaces, are structured at various levels.
> (Gibson, in preparation, p. 13)

Gibson is pointing out that we know, usually, what are the appropriate beginnings and ends to define the event, that events are natural units and this can be attributed to a "natural good fit" or attunement to the world. Giving an example, "stretching and relaxing is...an event in its own right and not a set of events - it cannot be reduced to a set of interrelated displacements of the elements on a surface" (Gibson, in preparation, p. 5). That is to say that whatever the event or its duration, this is specified as a "unitary episode" by the nature of the changes in the light we see. There are different kinds of changes in the array of light, for the different kinds of events. So it is these different kinds of changes that are the "stimuli" for perception and that specify the events that we perceive (Gibson, in preparation, p. 14).

> Does a stimulus last for a second, a millisecond, or a microsecond? Is it not theoretically preferable to suppose that a transformation is a stimulus in its own right, just as a nontransformation is a stimulus? Or better still that sequence (order in time) as well as pattern (arrangement in space) is a variable of stimulation? (Gibson and Gibson, 1957, p. 136)

The idea here is that a particular sequence of transformations or changes in the structure of the light array will always specify a particular event. Is it possible that the very same sequence of transformations can specify *different* events, depending on the rate of the change in the structure of the light array? We are suggesting that temporal properties, as much as geometrical properties, of transformations are what specify to us the nature of the event we are perceiving. That is, depending on the rate of change, what is specified as the transformational invariant and what the structural invariant may differ and therefore also the *kind* of event seen will differ.

The present study set out to explore by means of a particular, already much researched dynamic event whether this given event might have a usual or "ecologically normal" rate at which the sequence of transformations *always* specifies that kind of event. When this event occurs at a rate considerably slower than usual, it may mean that observers would see some portion or part of the total transformation to be the "unitary episode" and that an altogether different kind of event would be seen.

We have, then, taken a rigid motion event (the shadow of a perspective transformation of a rigid object) and shown it to observers of different ages at very slow rates. The geometric aspects of the transformation, its sequence, and the differential or relative velocities

of the parts of the form have been held constant. Only the absolute rate of the change or motion has been varied. Our hypothesis was that at slower-than-usual rates of change, a rigid motion event might be seen instead as a nonrigid motion event.

If the capacity to integrate or differentiate changes into "bounded events" is a function of development, as E. Gibson (1975) has implied, then we expected young children to see "differently bounded" events, different unitary episodes (and therefore a different event) than adults when an event occurred at a slower-than-usual rate. A second hypothesis, then, was that young children would be more likely than adults to see the slower-than-usual rigid motion event instead as a nonrigid motion or deformation of shape. Whatever the possible explanation for such a difference (whether a developmental increase in the capacity to pick up or integrate a sequence of changes, or the various theorized developmental changes in the "processing" of visual information) the fact of such developmental differences, it was hoped, might contribute to an understanding of a temporal variable in the perception of events, especially slower-than-usual events.

Arguing in a similar manner, if developmental differences in perception of rigid motion should occur at all rates of speed, evidence could be adduced in favor of a Piagetian position which would argue that the perception of rigid motion in depth would depend on the existence of cognitive structures subserving the representation of three dimensional, Euclidean space.

A specific issue was whether previous experience or the effect of "having been shown" a recognizable rigid motion event would (as

Neisser, 1976, Wallach, O'Connell & Neisser, 1953, and even E. Gibson, 1969, might have expected) facilitate seeing the transformation as a rigid motion event, even when it occurred slowly. Do we know from "previously acquired information" or from having been "shown" the transformational invariant what the "bounded structure" or the unitary episode of the present event must be? Does a previous experience help us see that the event is made up of a family of transformations that is small or big and extended?

Might adults be more likely than children to "learn" from a just-seen transformation, and therefore to detect a common transformational invariant in a subsequent event?

A third hypothesis, then, was that adults, once they had seen the same transformation at a "usual" rate, as a perspective transformation of a rigid object, would always see the transformation as a rigid motion event, regardless of its rate of change.

The aim of the present study, then, was to investigate if indeed a given kind of event might have a range of "usual" rates at which it is _always_ seen as that kind of event, then what happens to the perception of that same sequence of transformations when it occurs more slowly than usual? We were, then, exploring developmental differences in the perception of a given event, a rigid motion in depth, when it occurred at an unusually slow rate of change.

CHAPTER II: METHODS

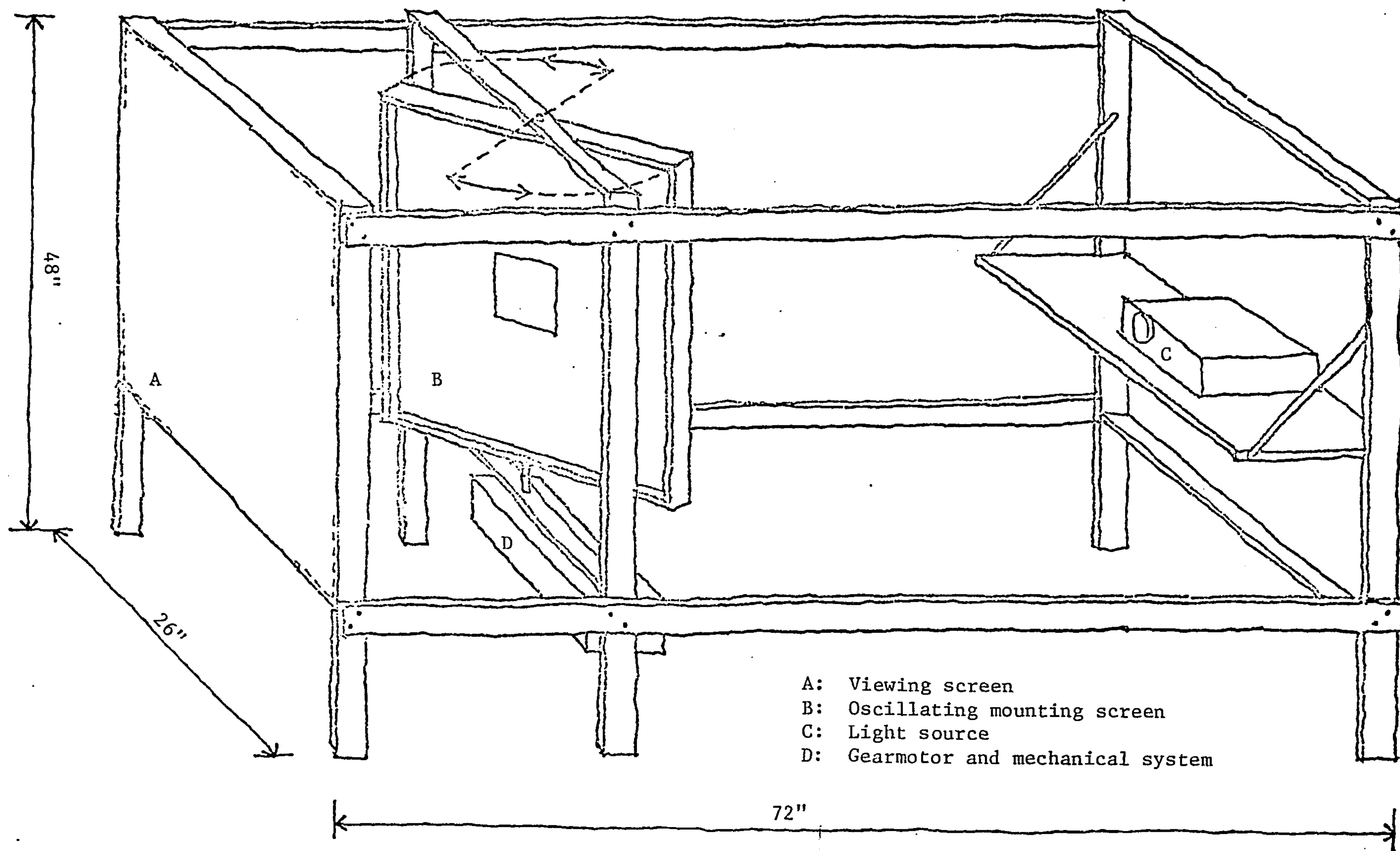
METHODS

Apparatus

A shadow caster was used, similar to the one used in the Gibson studies (1957a, 1957b, 1959). A five inch square form was mounted on a clear 24" plexiglass screen that could be rotated on a central vertical axis. The mounting screen was 48" from the light source (a high intensity slide projector lamp, giving a polar light projection) and 18" from the viewing screen (translucent plexiglass) on which the shadow was projected (see Figure 1). The sides, top, and bottom of the box-like structure were covered with rigid cardboard panels to conceal the "machinery" and to prevent reflections of light outside the structure. The rotating mounting screen moved continuously through a 90 degree path going 45 degrees off the parallel (in relation to the viewing screen) on both sides. To ensure smoothness and continuity, the movement was directed by a mechanical system which translated the rotary movement of the motor into a back-and-forth oscillation of 90 degrees. The mechanism was powered by a multiratio gearmotor which had rates of 1, 2, 3, 6, and 15 rpms. (The 15 rpm rate gave a four second cycle, the speed used by White and Meuser, 1960; Farber, 1972 and several others who have worked with the kinetic depth effect. Much of the previous work, however, has been with a 30 rpm rate). The light source and motor were controlled by separate switches outside the box structure and could be turned off between exposures whenever the rate was changed.

The form used for projection was a 5 inch square, cut out from construction paper, attached "invisibly" with double stick tape to the center of the plexiglass mounting screen. In pilot studies observers

Figure 1. Shadowcasting Apparatus



of all ages had uniformly reported seeing the square oscillating on its vertical axis (a rigid motion in depth) when moving at "fast" rates, as in the four second cycle.

The subject was shown (in all conditions) a continuously moving shadow. The presentation always began with the oscillating screen in a position at an angle, rather than parallel, to the viewing screen, so that the initial view of the shadow was not a perfect square projection. This led to a lack of control over the particular position in a cycle at which the stimulus started. A subject never saw any shadow in a stationary position; the light was turned on only after the motor was running and was turned off before the motor was stopped.

Subjects

The two parts of the study were conducted as separate experiments with separate subject groups in each of the three conditions, Experiment I, Experiment IIA, and Experiment IIB. Subjects were from four age groups: Group I consisted of 4 and 5 year olds (mean age: 5 years); Group II consisted of 8 and 9 year olds (mean age: 8 years, 8 months); Group III were 12 and 13 year olds (mean age: 12 years, 10 months); and Group IV were adults (mean age: 30 years). There were 20 subjects in each age group in each experiment (a total *N* of 160). In each age group, within each of the three conditions, there were equal numbers of males and females.

The subjects were from a middle class, urban population. The children were enrolled in the Bank Street School for Children in New York City. The adults were members of the staff of that school or graduate students in training there.

General Procedure

Every subject in this study was run individually. Each was introduced to the task by the explanation that he or she would be watching shadows. The "shadow box" was in a small, separate room. Children were asked if they had played with shadows before, and using the nearest wall or floor where a good shadow could be cast, E pointed out the correspondence between the shadow and what made it, "Look over here at the shadow of my hand on the wall. I can make a shadow with one finger or two fingers. You see, when I move my fingers, the shadow moves. Now you make a shadow....Can you make it move? You see, when you move your hand, the shadow moves too." S was then shown where to sit, on a chair three feet in front of the screen.

To assure that each subject would be able to give a clear description of the movement he would see, a practice example was given, using a movement unlike any of the possible motion percepts of the shadow to be seen. E showed subjects in age group I a flat model of Batman which hung from a string. E held the end of the string so Batman was suspended over the front of the viewing screen and moved the model up and down in the vertical plane asking "What's Batman doing?" The purpose was to elicit a verbal, and especially, a demonstrative description. E said, "Pretend your hand is Batman; show me what he's doing; make your hand do the same thing Batman's doing." Later, E used the model to make a circular movement over the vertical surface, or a horizontal side to side movement, each time saying, "Make your hand do the same thing Batman's doing," until S had imiated the path of movement correctly. Even the youngest subjects managed this imitation almost

immediately. When a subject had difficulty, E also, for example, invited S to correct her by moving her hand in a horizontal path while Batman moved up and down, and E asked S, "Is this what Batman's doing?" until S himself had correctly described the movement, even if in imitation of E's hand which was correctly demonstrating the actual movement of the model. Other imitations were continued, if necessary, until S imitated the model's movement directly and correctly. Any child who did not achieve this was excluded from the study. (This included approximately four children from the youngest age group.)

Subjects in age group II, out of respect for more grownup sensibilities, were shown a paper airplane with the instruction, "In a minute we're going to show you some shadows on the screen. Each time, I'll want you to tell me with words and with your hands just what the shadow is doing while you watch it. I'll need to be able to understand just what you mean so we're going to practice for a moment with this plane. How would you show me what the plane is doing? Make your hand do the same thing the plane's doing." Again, horizontal, vertical, and circular (in the vertical plane) paths of movement were used for practice.

To allay magical ideas about the shadows or any notion that they were being projected from films the subject was told, "This is a shadowbox and when the light goes on you'll see a real shadow here on the screen." To acknowledge the plane surface of the screen and help discount its two dimensionality from influencing the response, the analogy with a TV screen was made (which is also two dimensional but, while viewing, we take for granted the potential of seeing information for

three dimensional events). "Now you're going to see the first shadow up here on the screen. It's going to be a little like watching TV. You'll look at the shadow and show me what it's doing. Keep your eyes on the shadow all the time even while you're showing me. Ready? Say when to start." As soon as the presentation began (when the light went on), E asked, "What's going on?" and, if necessary, further, "What's this shadow doing?" (After Michotte's inquiry procedure, 1963, p. 296).

Each rate presentation involved a separate inquiry, carried on while the shadow was still being shown. This procedure was designed to avoid reliance on memory of the stimulus, which was not the task at hand. The task was rather for subjects to demonstrate what they saw. That response relied on imitative rather than representational or reconstructive capacities, so that younger subjects with less verbal or graphic skill had a means of giving a clear response in describing the motion they saw. Subjects of all ages were asked to demonstrate the movement with their hands but either verbal or demonstrative responses were recorded, whichever came first. E asked, "Show me with your hands what the ______ is doing," using, in the blank, whatever S had used to describe the shadow (e.g., "square," "black thing," "box," "shadow," "door"). If the verbal response and the demonstration together remained unclear, a subject could be given a paper cut out square which had been pre-rumpled to allow for easy folding and squishing demonstrations without worry of damaging the model. (Models of different colors were available for different presentations). E asked "Make [it] ("the paper" or "your hand") do the same thing the ______ is doing." Only a few of the younger children found it difficult

to imitate the movement with their hands and made use of the paper. When subjects gave a response combining expansion and turning, they were asked to specify while watching the shadow when they saw which kind of change. (This was an unrewarded attempt to distinguish clearly between those percepts where the two kinds of change were being seen simultaneously or successively).

After each rate presentation, there was a pause with no shadows. Then S was asked, "Ready for the next shadow?" and children were told to say when the presentation should begin, "Tell me when to start." The next rate presentation was then shown and the same request for description was made.

During the presentations E sat next to S in a location where S's hand demonstrations and the shadows could be seen at the same time. The switching on and off of the apparatus' light and motor, and the changing of rotation speeds were controlled by an assistant who went through the same gestures (including reaching through the opening in the box to change speeds) with every subject, regardless of the condition being presented (i.e., even in condition IIA where speeds were not actually changed). The assistant had been introduced to each subject and generally had had some contact with each S in the classroom, before the shadow task.

Experiment I

This first part of the study explored the effects of slowing down the rate of an event, in particular a rigid motion in depth. The same optical information (geometrically speaking) was used, which, when seen at "fast" rates (15 or 30 rpm) has been shown by many researchers to

be sufficient to specify a rigid motion event. Experiment I investigated whether a different event might be seen from the same sequence of transformations in the optic array if the transformations occurred more slowly. If the idea that the "temporal resolution" of the perceptual system increases with development (Bower, 1967) were correct, we expected that children would have difficulty with unusually "slow" events; for example, that children would have difficulty detecting this rigid motion event if it occurred at significantly slower-than-usual rates. We expected, if the developmental hypothesis held, that children seeing this shadow transformation would tend to see two dimensional distortions of shape (a nonrigid motion event) at rates of presentation at which older observers would see rotation in depth (a rigid motion event). In Experiment I, then, observers saw a sequence of five different rate presentations of the same shadow transformation.

The order of presentation rates was from slow to fast since pilot work had demonstrated that any other arrangement of presentation rates tended to mask the spontaneous percepts of slow rates. Accordingly, in this experiment the rates of presentation proceeded in the order: 1 rpm, 2 rpm, 3 rpm, 6 rpm, and 15 rpm.

Subjects

Subjects were ten males and ten females in each of the four age groups, a total N of 80. Only those subjects were excluded (four children from the youngest age group) who were unable to give a correct demonstrative response by the end of the practice in the introductory procedure.

Procedure

Each subject was individually introduced to the task according to the procedure already described. He or she was then presented all five rates of presentation of the shadow in ordered sequence from the slowest moving to the fastest (1, 2, 3, 6, and 15 rpm). Thereafter, the subject was exposed to repetitions of the 15 and 1 rpm rates under the countersuggestion conditions described below. (In further references to the various rate presentations and the responses to these presentations, the symbol "rpm" will be dropped. Presentations and responses, then, will be labelled as 1a, 1b, 3, 6, 15, 15CS, 1R and 1CS, respectively).

Latencies. For each rate of presentation the latency, or reaction time before the response was made, was recorded in seconds with a stopwatch. The time interval began when the shadow presentation was switched on and ended when the subject began his response, whether verbally or with a hand demonstration.

Pilot work with four and five year olds had shown that Ss who received instructions to respond as quickly as they could had latencies no different than subjects who had not been given this instruction. Therefore, no such instruction was given in the actual experiment.

At the slowest rate of presentation (1 rpm) subjects sometimes gave one response and after looking a bit longer gave a second, different response. Here the latency for the first response (1a) was recorded and two response categories were recorded (1a and 1b), either identical responses if the subject did not change his response, or the two different responses if that were the case.

The shadow presentation at each rate was not limited in time, but was continued until the subject had given a full descriptive response. At the slowest rate of presentation (1 rpm), unlike at other rate presentations, the shadow was shown for a minimum of 35 seconds. (This was because preliminary work had shown that, unlike at other rate presentations, subjects often changed responses at 1 rpm and that those who gave second responses generally did so before 30 seconds had elapsed). Other rate presentations had no minimum exposure time and ended when a subject signalled that he had completed his prior response.

Countersuggestions to Responses. As a means of testing to what extent the percept reported was "compelling" to a given subject, there was further inquiry after the response had been recorded for the last rate of presentation in the sequence (15 rpm). Here, alternatives to his own response were suggested to him as described below. A subject could accept or reject each of the alternatives as possible good descriptions of "what's going on" in that particular rate presentation.

Following the countersuggestion inquiry after 15 rpm, the first and slowest (1 rpm) rate presentation was shown again (presentation 1R) and S was asked to describe and demonstrate what he saw. This response was recorded as the "1R" response and it, too, was then challenged by suggestions of alternative responses. "1CS" responses to the countersuggestions after 1R were recorded separately. There were, finally, three alternative responses of which each subject was asked to consider as possible good descriptions the two he had not mentioned spontaneously. Since any of the three descriptions could be accepted or rejected in any combination, there were seven possible categories for both 15CS and 1CS responses.

For example, if S's response had been "turning" (R) the countersuggestion was made, "Do you know what, another boy (or girl) who looked at this told me it was getting big and little. He said it only gets fat and skinny and never turns. Do you think he (or she) was right?" S's response to this was recorded as an acceptance (+) or a rejection (-) of E. A further countersuggestion of B was made, "There was another boy (or girl) who told me something else. He (she) said it was turning like this (E demonstrates with hands) and getting big and little at the same time. Do you think that boy (or girl) was right?" S was encouraged after each countersuggestion was made, to keep looking at the shadow, which was being shown continuously, to determine whether the alternative description seemed to him to match the phenomenon, "Keep looking at the shadow and tell me what you see. Could it just be _____ing?"

Recording of Responses

Categories of response for rate presentations 1 to 15 and 1R. For each presentation responses were recorded by category. There were eight categories of response originally hypothesized as "theoretically possible":

E Expansion/contraction (nonrigid motion)

R Rotation, oscillation back and forth (perspective transformation, rigid motion in depth

B Both A and B simultaneously within a cycle

C Both A and B successively but within the same cycle (1 min. at 1 rpm, 4 sec. at 15 rpm)

D Both A and B successively within the same presentation but not within the same cycle

X Looming and recession

Y Translation from right to left of screen, always in vertical plane

Z Tilting from side to side in vertical plane

Of these categories, the last three never occurred in subjects' response histories. Categories E, R and B which were by far the most frequent, were equivalent to three of the ten kinds of "disturbances of optical structure" that, according to Gibson, correspond to "events" (Gibson, 1976, p. 22). In fact, categories C and D, which occurred extremely infrequently, were variations of these.

The responses in which both expansion and rotation were perceived successively (C), or simultaneously (B), within the same cycle of oscillation were in actuality very difficult to distinguish accurately, when given by subjects of any age group. They were, then, logically collapsed as both C and B dealt with the two kinds of changes being perceived within the same oscillation cycle.

The proposed category D, indicating a shift between a percept of expansion and of rotation within the same rate presentation (but not the same cycle) only occurred at the slowest rate presentation (1 rpm) and could be handled by the sequential 1a and 1b responses, recorded separately. Only at 1R, apparently as a result of the countersuggestion, 15CS, were there shifts back and forth between E and R responses (e.g., ERE). This occurred only among three adult subjects and was recorded as "E/R," in order to distinguish this kind of percept from either E, R or B.

Without any real violence to the data, then, responses to the five rate

presentations and 1R could be accurately coded as belonging to categories E (expansion/contraction), R (rotation) or B (some combination of both expansion and rotation within the same cycle). (With the addition in three adult cases of the E/R "D-like," category for 1R.)

Categories of response for countersuggestions 15CS and 1CS. In these two trials subjects could accept or reject each of the alternatives. Seven possible categories of combinations emerged. For each countersuggestion inquiry (15CS and 1CS) then, subjects were recorded as responding according to one of the possible categories of combinations.

The seven possible categories (according to which of the three responses the subject accepted or rejected, separately or conjointly) are encoded below in terms of a three bit code where "+" indicates acceptance of a descriptive response and "-" indicates rejection. Response E, again, is a description of "expansion," R corresponds to "rotation," and B is some combination of both expansion and rotation together.

CS Category	Code			Description
	E	B	R	
1	+	-	-	only E, not B or R
2	+	+	-	E or B, not R alone
3	+	-	+	E alone or R alone, but not both together (B)
4	+	+	+	E alone, R alone or B (Both E & R together)
5	-	+	-	only B, neither E nor R alone
6	-	+	+	B or R alone, not E alone
7	-	-	+	only R, not E or B

Experiment II

In order to control for two aspects of the sequential presentation in Experiment I, two conditions (each with separate observers) were examined separately in Experiment II for their capacity to account for shifts of percepts. Experiment IIA focussed on the repetition effect: would an observer begin to see the shadow transformation as a rigid motion if he looked at it often enough, regardless of whether the transformation occurred at increasingly faster rates (as in Experiment I)? To test the independent effect of repetition in this situation, subjects in Experiment IIA were shown three repetitions of the slowest (1 rpm) rate presentation (slow/slow/slow).

Another question in relation to Experiment I was tested in Experiment IIB: would an observer who had seen the transformation as a rigid motion event on one presentation, always see subsequent presentations as the same kind of event, regardless of the rates of change of the subsequent presentations? To test the effect of "having seen rotation," subjects in Experiment IIB were shown a slow/fast/slow sequence of rate presentations. In both conditions IIA and IIB the interest was in terms of whether anything besides the continuously increasing rates of presentation could account for the shifts in percepts at different rate presentations in the Experiment I sequence: how would shifts in percept by the final presentation in conditions IIA and IIB compare with the shifts in percept in Experiment I?

The two rates chosen as "fast" and "slow" were based on results from Experiment I and determined separately for each age group. The slowest rate at which 14 (70%) of the 20 subjects in an age group gave a rotation (R) response in Experiment I was called the "fast" rate for

that age group in Experiment IIB. (Accordingly, this "fast" rate was 15 rpm for age groups I and II, and 3 rpm for age groups III and IV.) However, for the slow rate, no such percentage-per-age group from Experiment I could be utilized (as even in the youngest age group, only thirteen subjects continued to see expansion on response 1b) and we were "mechanically" limited to 1 rpm as the slowest rate. Therefore, subjects were selected in Experiment II who might potentially shift responses; that is, subjects who saw rotation (R) at 1 rpm were eliminated from Experiment II since we could have learned little from them about the effect of immediately previous experience in terms of maintaining or shifting away from an expansion percept. (No selection criteria of any kind, except the capacity to respond demonstratively, had to be met by subjects in Experiment I.)

Subjects

Ten subjects in each of the four age groups (equal numbers of males and females) were presented each of the two conditions. That is, conditions IIA and IIB each were presented to a separate sample of 40 subjects; the total _N_, then, in Experiment II as a whole was 80. These _Ss_ were an entirely independent sample from Experiment I and were preselected on the basis of having _not_ seen rotation (R) by the end of the 35 second first presentation of the 1 rpm rate.

Procedure

The same introductory procedure, instructions and inquiry as in Experiment I were used for the three exposures a subject saw, whether he was presented condition IIA (slow/slow/slow) or condition IIB (slow/fast/slow).

In condition IIA subjects of all age groups were shown a repetition of the slowest (1 rpm) rate presentation. After the response to the last rate presentation, alternatives to the subject's spontaneous response were countersuggested (1CS).

Based on results from Experiment I as to what constituted a "fast" rate for a given age group, in condition IIB (slow/fast/slow condition) subjects in age groups I and II (4 to 5 and 8 to 9 year olds) were presented a 1 rpm/15 rpm/1 rpm sequence before the 1CS countersuggestion. Subjects in age groups III and IV (12 to 13 year olds and adults) were presented a 1 rpm/6 rpm/1 rpm sequence of rate presentations and then the 1CS inquiry was made. In Experiment II, then, only one countersuggestion inquiry (1CS) was made to the last presentation rate which was "slow" (1 rpm).

Recording of Responses

Verbal and demonstrative responses were categorized and recorded in the same way as in Experiment I. The countersuggestion inquiry after the last response in the sequence of three presentations of the shadow, was also carried out, and the 1CS responses recorded, in the same manner as in Experiment I.

CHAPTER III: RESULTS

RESULTS

Experiment I

Table 1 presents all responses, in the order they were made, for all 80 subjects. As previously described, except for the countersuggestion trials (15CS and 1CS), responses were coded as E (expansion contraction), R (rotation) or B (both E and R), while for 15CS and 1CS they were coded according to a seven digit format. Within each age group the subjects' scores are arranged in ascending order of R responses, i.e., those nearest the bottom saw R at slower rate presentations than those near the top.

Changes in Percept

One of the most striking findings of the study is that from 1a to 15, the responses E, B, R always appeared in some version of that progression in *every* subject's series of responses. Stated another way, no "reversal transitions" (e.g., R to E, or R to B, or B to E) ever occurred. As is apparent from Table 1, there were only six possible transitions: remaining with the same percept of the event as earlier (E to E, B to B, R to R), shifting from expansion to combination (E to B), or from a combination to a rotation response (B to R), or shifting from a pure expansion to a pure rotation response (E to R). Once having arrived at R, with increasing rate presenation, no subject ever left it. In this context then, the percept of rotation alone can be said to be an "absorbing response" in the Markovian sense (Coombs, Dawes and Tversky, 1970).

Arrival at the percept of R is not obligatory. Among the 80 *S*s,

three 4-5 year olds, and one each from the two oldest age groups never saw rotation alone, even at the fastest rate presentation.

Age and rate differences in the changing of responses. The preceding finding does not necessarily imply that all subjects move from one percept to another at the same rate, nor even that any subject necessarily passes through the transitional B phase. In the face of enormous variability of patterns seen in Table 1, attempts were made to assess the questions of whether the probabilities of changing response varied as a function of age group or presentation rate. To assess each question independently, it was necessary to seek appropriate sample sizes in Table 1, of which three were found:

1. Of thirteen Ss in the youngest age group who still perceived expansion at 1b, nine continued to do so at 2 rpm. Conversely, of thirteen Ss in the three older age groups who still perceived expansion at 1b, only three continued to do so at 2 rpm. This disparity was assessed by Fisher's Exact Test (Siegel, 1956) and found to be significant ($p < .025$). Thus there is a difference in the probability of remaining in percept E as a function of age, the youngest group tending to remain in E, the older groups tending to relinquish E for B or R.

2. In the youngest age group (4-5), seven Ss who saw B at 2 rpm continued to do so at 3 rpm. Conversely, of seven Ss who saw B at 6 rpm, only two continued to do so at the next higher rate presentation of 15 rpm. As assessed by Fisher's Exact Test, this difference was significant ($p < .025$).

3. The same test was made with the next but youngest age group (8-9). Here there were ten Ss who saw B at 2 rpm of whom nine continued to do so at 3 rpm. By 6 rpm there were seven Ss reporting B, all of whom switched to R by 15 rpm. This discrepancy was highly significant ($p < .01$).

Thus for the two youngest age groups, slow presentation rates support the maintenance of a given percept while faster presentation rates provoke shifts toward rotation percepts (B to R). Taken together, these three findings indicate that, although the possibilities of transitions are limited, their probabilities vary as a function of age and presentation rate.

Age differences in rates of transition. The preceding findings permit comparisons among the four age groups regarding possible differences in their rates of transition through the EBR progression. Two such tests are described in Tables 2 and 3, where first the four groups are compared with respect to their rates of abandoning the percept of expansion (E) and then compared with regard to their rate of attaining the percept of rotation (R), both as a function of presentation rate (rpms). As seen in the tables, the youngest group abandons the percept of E and begins to see rotation (R) at faster presentation rates than the older age groups.

For both tables, each age group was compared with each other age group by means of the Kolmogorov-Smirnov Test (Siegel, 1956) with the result that none of the three older age groups could be differentiated. Conversely, the youngest age group differed from each of the older groups even more significantly with increasing age.

In Table 2, the ascending age comparisons with age group I yield K_D differences of 8, for group II ($p < .05$), 9 for group III ($p < .025$) and 10 for group IV ($p < .01$). In Table 3, the same comparisons with age group I yield K_D differences of 5 for group II ($p > .05$), 10 for group III ($p < .01$) and 12 for group IV ($p < .005$). Since this finding confirms our expectation of a developmental trend, the preceding probabilities are specified for one-tailed tests.

Responses to Countersuggestions

Responses to 15CS. Responses to the 15CS countersuggestions were nearly uniform among all subjects, regardless of age group and therefore all age groups will be considered together.

As seen in Table 1, by the end of the five rate presentations (15 rpm), 75 subjects reported seeing the phenomenon as a rotation (R). When alternatives of expansion (E) or some combination of expansion/rotation (B) were countersuggested, 69 of the 75 subjects rejected the countersuggestion and denied the phenomenon could be anything but a rotation. Two among the five subjects who had not seen rotation by 15 rpm accepted rotation as a fitting description of the phenomenon, once it was suggested to them. In response to the countersuggestion after 15 rpm, then, 71 subjects could not be persuaded away from a pure rotation as an explanation of the phenomenon, eight subjects accepted rotation (R) or some combination (B) of rotation and expansion as both being possible descriptions, and only one subject (a 4 year old who had never seen either E or R but only seen B from the beginning of the sequence) rejected rotation as a description of the phenomenon. In sum, then, 70 of the 80 subjects in the 15CS condition stood by their judgements and resisted countersuggestion.

Responses to 1R. In response to the repetition of the 1 rpm presentation following 15CS, all but three of the Ss made E, B, or R responses. The exceptions were three adults who saw E or R alternately and repeatedly but never in combination (B). Considering that this response occurred only in 1R, it seems reasonable to attribute its occurrence to the countersuggestions on the preceding trial.

Table 4 shows the distribution of E, B, and R responses for the four age groups. As seen in this table there is no regular relation between the nature of 1R responses and age group, other than that E percepts (expansion) are somewhat less probable than B or R responses. Attempts were made to relate any aspect of subjects' responses on 1R to response histories from 1 rpm to 15 rpm, e.g., whether on presentations 1 to 15 they had seen B, or had never seen B, or saw R early in the presentation sequence, but no overall regularities emerged. Only in the youngest group was there found a relationship to earlier responses:

Of eleven subjects who had seen B previously in earlier responses, only four failed to give B responses on the 1R presentation, while all nine subjects who had never seen B previously, never saw B on 1R. When this disparity was assessed by Fisher's exact test, the probability of its occurrence by chance was less than .005.

Responses to 1CS. As shown in Table 4, responses to 1R were not nearly as uniform as those to 15 rpm. When alternatives to whatever was seen in the 1R presentation rate were examined with respect to whether the countersuggestions were accepted or not, only 35 out of the 80 subjects rejected the countersuggestions. Table 5 shows the distribution

of subjects' responses on 1CS in relation to their 1R responses. Responses of subjects resistant-to-countersuggestions fell into the exclusive categories 1, 5, and 7. (The three adult E/R responders on 1R were in 1CS category 3.)

Comparison of 15CS and 1CS. Comparison of the tendency to reject countersuggestions in the 15CS vs. the 1CS condition indicates that subjects were far more likely to reject countersuggestions in the 15CS case. The contrast between likelihoods of accepting countersuggestions at the two rates is significant by McNemar's Test ($\chi^2 = 26.9$, $p < .001$).

Latencies (reactions times)

As previously noted, response latencies were recorded for all five presentation rates. Table 6 presents the means and standard deviations for each age group at each presentation rate, including 1R.

As shown in Table 7, an analysis of variance revealed no significant differences among the four age groups but highly significant differences ($p < .001$) among the presentation rates. Post hoc Tukey tests established that latencies were briefest for responses at presentation rate 15 and longest for 1R, the remaining presentation rates having intermediate latencies which were indiscriminable from one another. Presumably the briefer latency at 15 rpm was in some degree determined by the very brief (4 sec.) cycle time. Likewise, the long latency at 1R is explained by a cautiousness provoked by the just preceding 15CS trial.

No relations were found between latencies and response categories (E, B, or R), nor was there any difference among latencies in the various possible transitions from one response category to another.

Experiment II

Table 8 shows the sequence of responses given by each subject in the two conditions of Experiment II by age group. The first regularity to be discerned is that all but three Ss in IIB saw the second rate presentation as pure rotation (R). Conversely, in IIA, the responses are almost evenly distributed amongst E, B, and R (15, 13, and 12, respectively). Despite this difference on the second trial, the two groups of subjects cannot be distinguished at the third rate presentation. The proportions of E, B, and R responses are 10, 17, 13 for IIA and 10, 15, 15 for IIB. This same lack of difference in third presentation responses obtains when the age groups in IIA and IIB are individually compared.

Changes in Percept

An attempt was made to determine whether Experiments IIA and IIB might not differ in respect to the relationship of Trial 1 responses to Trial 3 responses. Table 9 presents the results of this analysis. By inspection the two matrices are remarkably similar, permitting the assertion that seeing the phenomenon repeatedly (IIA) does not increase the likelihood of seeing it as a rotation nor does the fact of having experienced an intervening rotation phenomenon (the second presentation in IIB) increase the likelihood that when the slowest rate presentation is repeated it will be seen as a rotation.

This suggests that the EBR response progression, and R as an "absorbing" percept, as found in Experiment I, is a function of rate of presentation, rather than intransigence in switching percepts, once rotation has been seen. Experiment IIA suggests, in terms of Experiment

I, that neither is it merely a function of seeing the same phenomenon again and again, that brings subjects to see rotation eventually in the course of the presentation sequence, but rather that this pattern in Experiment I is a function of the increasing rate of the changing phenomenon as the presentation rates increase during the sequence of presentation.

Age differences in the changing of responses. In IIA there is a strong tendency, though not quite significant, for the older two age groups to change percepts more than the younger age groups, when we compared over the three possibilities of a) never changing percepts throughout the three trials, b) changing category of response once, or c) changing category of response twice over the three trials.

In IIB, when we compare the first and third trials we find a similar tendency (though, again, not quite significant): younger subjects do not change responses as much as older subjects. When we combine changes in IIA between trials 2 and 3 with changes in IIB between trials 1 and 3 (in terms of comparing the last response with the most recent exposure to 1 rpm, since responses on trial 3 in both IIA and IIB are indistinguishable) this trend is significant ($\chi^2 = 5.08$, $p < .05$): older subjects change their responses (toward R) significantly more than younger subjects who tend to see the same percept as they did the last time they saw 1 rpm.

Responses to 1CS

Table 10 compares responses in IIA and IIB to the countersuggestion after the third presentation (1 rpm). Here too, there is no basis of discrimination between the two conditions of Experiment II. When the

table is compared with the results for Experiment I (Table 5) trends of resistance to countersuggestions are noted similar to those already described.

Relating Experiments I and II

Several direct comparisons may be made between Experiments I and II. Each of them supports the conclusion that it is the increasing rate in Experiment I that accounts for the shifts toward percepts of rotation.

One test compares the third trial responses in both experiments, where in II this is a repetition of 1 rpm while in I it corresponds to the 3 rpm presentation. Whereas in II the mix of E, B, R responses was 20, 32, and 28, in I the mix was 5, 27, and 48. This great disparity was highly significant ($\chi^2 = 14.7$, $p < .001$), owing principally to the shift toward R in I.

Another contrast can be made by comparing subjects' behavior in the two experiments following the perception of rotation. In IIB, of 37 Ss who saw rotation on the second trial (15 rpm) only fifteen continued to see R on the next trial (1 rpm). In I, of 61 Ss who saw R on one trial (6 rpm) all 61 continued to do so on the next trial (15 rpm). This huge difference ($\chi^2 = 43.5$, $p < .0001$) clearly rejects any possible claim that having seen R one necessarily will continue to do so.

The previous tests included Ss of all age groups, which can only serve to dilute the differences between Experiments I and II, considering that the youngest age group did not perform discriminably differently in Experiments I, IIA or IIB, on the third trial.

The youngest group is thus excluded from a final contrast of pure repetition in Experiment IIA with increasing rate of presentation in Experiment I.

For this analysis we restricted our attention to those 42 *S*s in Experiment I who have not yet seen R by the end of the first presentation, since no such *S*s were permitted to enter IIA. Thereafter we compared the responses in Experiments I and IIA on Trials 2 and 3 according to a scale which weights the responses in terms of degree of rotation seen (E = 1, B = 2, R = 3). Table 11 presents the results of this analysis, where disparities between the two groups are immediately apparent. Whereas IIA subjects are evenly distributed across all possible response combinations, Experiment I subjects clearly shift toward B or R responses. The difference was assessed by a one-tailed Kolmogorov — Smirnov Test and found to be significant (Dmax = 319, $^{2} = 7.12$, $p < .05$).

It can be concluded that the lack of difference in the youngest age group among the three experimental conditions of repetition of the 1 rpm rate presentation is not merely a function of their lesser susceptibility to any effect of repetition, neither is it merely a function of some greater intransigence in terms of changing responses, but that the tendency not to change response is indeed a reflection of their *not seeing* rotation at low rate presentations. (At faster rate presentations, e.g., 15 rpm in IIB, all youngest subjects *do* shift to rotation responses). Differences between youngest and older age groups, then, cannot be attributed to the greater "changeability" of older subjects' response behaviors, or to the greater effect of repetition on older subjects. The above comparison with Experiment I shows there is a "rotational imperative," a significant tendency to see rotation at faster rate presentations, which is present in

Experiment I and absent in the repetition condition, Experiment IIA. It can be concluded, then, that subjects in the youngest age group are influenced by this "rotational imperative" only at faster presentation rates.

Table 1

Response Histories for Experiment I by Age Group

Age Group

Subject Number by Age Group	4 - 5 N=20								
Presentation (RPM)	1a	1b	2	3	6	15	15 CS	1 R	1 CS
1	E	E	E	E	E	E	7	E	4
2	E	E	E	B	B	B	5	B	5
3	B	B	B	B	B	B	2	B	5
4	E	E	E	E	B	R	7	B	5
5	E	E	E	B	B	R	7	B	5
6	E	E	B	B	B	R	7	B	5
7	E	E	B	B	B	R	7	E	1
8	E	B	B	B	B	R	7	B	5
9	E	E	E	E	R	R	7	R	7
10	E	E	E	E	R	R	7	E	4
11	E	E	E	E	R	R	7	R	7
12	E	E	E	E	R	R	7	R	7
13	E	E	B	B	R	R	7	R	4
14	B	B	B	B	R	R	7	R	4
15	B	B	B	B	R	R	7	B	5
16	E	E	E	R	R	R	7	R	7
17	E	E	R	R	R	R	7	E	4
18	E	R	R	R	R	R	7	R	7
19	E	R	R	R	R	R	7	R	4
20	R	R	R	R	R	R	7	R	7

Subject Number by Age Group	8 - 9 N=20								
Presentation (RPM)	1a	1b	2	3	6	15	15 CS	1 R	1 CS
1	E	E	E	B	B	R	6	B	5
2	E	E	B	B	B	R	7	E	4
3	E	E	B	B	B	R	7	E	2
4	E	E	B	B	B	R	7	E	2
5	E	B	B	B	B	R	7	E	1
6	E	B	B	B	B	R	7	B	2
7	B	B	B	B	B	R	7	B	5
8	E	B	B	B	R	R	7	R	7
9	E	B	B	B	R	R	7	B	6
10	E	B	B	B	R	R	7	B	4
11	B	B	B	R	R	R	7	B	6
12	E	E	R	R	R	R	7	B	4
13	E	E	R	R	R	R	7	E	1
14	B	B	R	R	R	R	7	B	5
15	B	B	R	R	R	R	7	B	5
16	E	R	R	R	R	R	7	B	2
17	E	R	R	R	R	R	7	B	6
18	E	R	R	R	R	R	6	B	6
19	R	R	R	R	R	R	7	R	7
20	R	R	R	R	R	R	6	B	6

Subject Number by Age Group	12 - 13 N=20								
Presentation (RPM)	1a	1b	2	3	6	15	15 CS	1 R	1 CS
1	B	B	B	B	B	B	6	R	7
2	E	E	E	B	B	R	7	B	2
3	E	E	B	B	R	R	7	E	2
4	E	E	B	B	R	R	7	B	6
5	B	B	B	B	R	R	7	R	7
6	E	E	E	R	R	R	7	E	1
7	E	B	B	R	R	R	7	B	6
8	B	B	B	R	R	R	7	R	7
9	B	B	B	R	R	R	7	E	4
10	E	B	R	R	R	R	7	E	4
11	E	B	R	R	R	R	7	E	3
12	B	B	R	R	R	R	7	B	6
13	B	B	R	R	R	R	6	R	3
14	E	R	R	R	R	R	7	R	7
15	R	R	R	R	R	R	7	E	4
16	R	R	R	R	R	R	7	B	4
17	R	R	R	R	R	R	7	R	3
18	R	R	R	R	R	R	4	B	4
19	R	R	R	R	R	R	7	R	7
20	R	R	R	R	R	R	6	R	4

Subject Number by Age Group	Adults N=20								
Presentation (RPM)	1a	1b	2	3	6	15	15 CS	1 R	1 CS
1	E	B	B	B	B	B	7	B	5
2	B	B	B	B	B	R	7	E	4
3	E	B	B	B	R	R	7	E	4
4	B	B	B	R	R	R	7	B	4
5	B	B	B	R	R	R	7	R	7
6	E	E	R	R	R	R	7	R	4
7	E	E	R	R	R	R	7	B	4
8	E	E	R	R	R	R	7	E/R	3
9	E	B	R	R	R	R	7	B	5
10	E	B	R	R	R	R	7	R	3
11	E	B	R	R	R	R	7	E	1
12	E	B	R	R	R	R	7	E/R	3
13	B	B	R	R	R	R	7	B	4
14	E	B	R	R	R	R	7	R	3
15	B	R	R	R	R	R	7	B	4
16	R	R	R	R	R	R	7	R	3
17	R	R	R	R	R	R	7	B	5
18	R	R	R	R	R	R	7	E/R	3
19	R	R	R	R	R	R	7	R	7
20	R	R	R	R	R	R	7	R	7

Table 2

Cumulative Number of Subjects Giving B or R Responses by Age Group and Presentation Rate in Experiment I

	Age Group			
	I	II	III	IV
Presentation				
1a	4	6	12	10
1b	7	14	16	17
2	11	19	18	20
3	14	20	20	
6	19			
15	19[a]			

[a] One subject saw E throughout.

Table 3

Cumulative Number of Subjects Giving R Responses by Age Group and Presentation Rate in Experiment I

	Age Group			
	I	II	III	IV
Presentation				
1a	1	2	6	5
1b	3	5	7	6
2	4	9	11	15
3	5	10	15	17
6	12	13	18	18
15	17[a]	20	19[a]	19[a]

[a] Number of subjects never giving R response:
I - 3, III - 1, IV - 1.

Table 4

Frequencies of Responses on Presentation 1R by Age Group in Experiment I

	Age Group				
	I	II	III	IV	Total
Response Category					
E	4	5	6	3	18
B	7	13	5	7	32
R	9	2	9	7	27
E/R	0	0	0	3	3

Table 5

Frequencies of Response Pairs on 1CS and 1R in Experiment I

	Code [a]			1R Response			
Counter-suggestion Response Category	E	B	R	E	B	R	E/R
1	+	-	-	5			
2	+	+	-	3	3		
3	+	-	+	1		5	3
4	+	+	+	9	8	5	
5	-	+	-		14		
6	-	+	+		8		
7	-	-	+			16	

[a] (+) percept accepted, (-) percept rejected.

Table 6

Response Latencies by Age Group and
Presentation Rate in Experiment I

		Age Group				
		I n=20	II n=20	III n=20	IV n=20	Total N = 80
Presentation						
1a	M	7.30	8.55	6.70	8.65	7.80
	SD	4.95	4.44	2.98	6.41	4.83
2	M	7.60	9.50	8.10	11.65	9.21
	SD	8.57	6.23	3.98	10.09	7.60
3	M	5.70	10.20	7.95	12.60	9.11
	SD	2.76	6.33	3.15	6.15	5.44
6	M	8.60	9.45	7.00	8.75	8.45
	SD	16.97	6.52	3.99	5.73	9.59
15	M	5.00	5.50	4.80	6.45	5.44
	SD	3.11	1.91	1.61	3.60	2.71
1R	M	13.35	11.20	12.80	12.45	12.45
	SD	20.69	7.56	4.71	5.23	11.37

Note: All numbers are in seconds.

Table 7

Analysis of Variance for Latencies

	Sum of Squares	*df*	Variance Estimate	*F*	*p*
Age group	398.11	3	132.70	1.02	~
Within subjects	9,918.22	76	130.50		
Presentation rate	2,080.02	5	416.00	9.90	<.001
Age group by presentation rate	527.60	15	35.17	0.84	~
Presentation rate by subjects	15,963.44	380	42.01		
Total:	28,887.39	479			

Table 8

Response Histories for Experiment II by Age Group

Experiment IIa	Age Group 4 - 5				8 - 9				12 - 13				Adults			
Presentation (RPM)	1	1	1	1 CS	1	1	1	1 CS	1	1	1	1 CS	1	1	1	1 CS
Subject Number by Age Group																
1	E	R	R	7	E	B	B	4	B	B	B	2	E	R	R	6
2	E	R	R	1	E	E	E	4	E	E	B	5	E	B	R	6
3	E	R	R	7	E	B	B	4	B	R	B	6	E	E	E	6
4	E	B	B	5	E	E	E	4	B	B	R	6	E	E	B	2
5	B	B	B	5	E	E	B	5	E	R	R	6	E	R	R	4
6	E	R	R	4	E	E	B	6	B	R	R	6	E	B	R	4
7	E	E	E	1	B	B	B	5	E	E	E	4	E	R	R	3
8	E	E	E	1	B	B	B	5	B	B	B	5	E	R	R	7
9	E	E	E	1	B	B	B	5	E	R	B	2	E	E	E	3
10	E	E	E	2	B	B	B	5	E	E	E	1	E	E	B	6
Experiment IIb																
Presentation (RPM)	1	15	1	1 CS	1	15	1	1 CS	1	3	1	1 CS	1	3	1	1 CS
Subject Number by Age Group																
1	E	R	E	5	B	R	R	7	E	R	B	4	E	R	R	4
2	E	R	E	5	B	R	B	2	E	R	R	7	E	R	R	6
3	E	R	E	1	E	R	B	5	B	R	B	6	E	R	E	2
4	E	R	E	2	E	R	E	7	E	R	R	3	E	B	B	5
5	E	R	B	5	E	R	E	4	B	R	B	6	B	R	R	4
6	E	R	R	7	B	R	B	2	E	R	B	4	E	E	E	3
7	E	R	E	1	B	R	B	6	E	R	B	5	E	E	E	3
8	E	R	R	4	E	R	B	4	E	R	R	7	E	R	B	6
9	B	R	R	7	E	R	R	6	E	R	R	4	E	R	B	2
10	E	R	B	4	E	R	R	7	E	R	R	4	E	R	R	3

Table 9

Frequencies of Response Pairs on First and Third Presentations in Experiment II

	Experiment IIA			Experiment IIB		
	Trial 1 Response			Trial 1 Response		
	E	B	Total	E	B	Total
Trial 3 Response						
E	10	0	10	10	0	10
B	10	7	17	10	5	15
R	10	3	13	12	3	15

Table 10

Frequencies of Response to 1CS by Age Group in Experiment II

CS Response Category (Response Code AEB)	Experiment IIA					Experiment IIB					Combined Total 11A & IIB
	Age Group				Total	Age Group				Total	
	4-5	8-9	12-13	Adults		4-5	8-9	12-13	Adults		
1 (+ - -)	4		1		5	2				2	7
2 (+ + -)	1		2	1	4	1	2		2	5	9
3 (+ - +)				2	2			1	3	4	6
4 (+ + +)	1	4	1	2	8	2	2	4	2	10	18
5 (- + -)	2	5	2		9	3	1	1	1	6	15
6 (- + +)		1	4	4	9		2	2	2	6	15
7 (- - +)	2			1	3	2	3	2		7	10

Table 11

Frequencies of Response on Trials 2 and 3 Combined for Selected[a] Subjects in Experiments I and IIA

Response			Experiment I[b]		Experiment IIA	
Trial 2	Trial 3	Weight[c]	N	Cumulative Proportion	N	Cumulative Proportion
E	E	2	0	0	6	.200
E	B	3	2	.048	5	.367
B E	B R	4	17	.452	8	.633
B	R	5	6	.595	5	.800
R	R	6	17	1.000	6	1.000

[a] Only age groups II, III, IV.
[b] Only subjects from Experiment I who have not seen R by presentation 1b.
[c] E =1, B = 2, R = 3.

CHAPTER IV: DISCUSSION

DISCUSSION

The main finding of the study is that indeed the very same visual information that specifies a rotation event at one rate of change, specifies a very different event, an expansion, at another, slower rate of change. The "same" transformation (in geometrical terms) in the light array which specifies a rotational event when the transformation occurs quickly (15 rpm) defines a different kind of event when the transformation occurs slowly. (Ninety-two percent of the subjects who saw some form of expansion at 1 rpm, later saw rotation at 15 rpm). Not only does the percept, in most cases, vary with rate, but there is also an order or directionality to the shifts in percept, as the rate of presentation increases, from expansion to rigid motion percepts. Within the range of rates investigated in the present study, at slow rates of presentation there emerged age differences in the kind of event seen. Young children are more prone to see the transformation as an expansion when it occurs slowly than are older subjects. Older subjects see rotation at slower rates of change than do younger subjects who begin to see the phenomenon as a rotation only when the transformation occurs more quickly. At faster rates of presentation, however, subjects of all ages saw the transformation as a rigid motion event.

The results of this study suggest that the same transformation that specifies a rigid motion may be <u>seen</u> as a rigid or a nonrigid motion event, depending on the rate of the change. This "rate

dependency" is especially evident among young children.

That the rate at which a change takes place is part of what determines the kind of event the change specifies, is perhaps only an experimental proof of what common sense would tell us. It serves, however, to modify or extend Gibson's idea that a particular sequence of transformations or changes in the structure of the light array will always specify a particular event (Gibson and Gibson, 1957). It seems it is not just the pattern (arrangement in space) and sequence (order in time) that must be considered as variables of the transformation-stimulus, but also the rate at which the transformation takes place.

More specifically, our study qualifies the idea that "any continuous sequence of perspective transformations is the correlate of perceptually rigid motion" (Gibson and Gibson, 1957, p. 129). The present study confirms that, at all ages we worked with, this assertion is true - as long as the transformation takes place within the range of particular rates "fast" enough to specify to the observer, rigid motions.

As nearly all subjects achieved a rigid motion percept at fast rates, it does seem that the event is indeed specified by the particular transformation taking place, however, this specification is not simply based on the geometry of the changes in the light array, but is in some way rate dependent.

What is it then that makes the same stimulus transformation look like a different event when it occurs at different rates? What accounts for the age differences in percepts at slow rates of change that are absent at fast rates?

The importance of rate of change to what event will be seen, then, allowed us to test several possible theories about the detection of events. The developmental changes we found promised to help sift out some ingredients necessary for "veridical" event perception.

Possible Explanations

The perceptual tendency hypothesis. Our results seem to contradict Johansson's (1975) idea that we have a "primary perceptual tendency" an expectation or bias to see rigidity or three dimensionality from any two dimensional changes. Or at least, our findings would suggest, any "perceptual tendency" itself would only be operative when transformations take place quickly enough.

Previous experience. Another class of theories that this data addresses concerns those perceptual theories that invoke "previous experience" as a causal explanation. The basic idea is that we learn from what we have seen before that a given stimulus transformation corresponds to a given event. It would seem, then, that it would be necessary to have learned this correspondence in order to differentiate one event from another. Whatever the "learning" that might be supposed to be lacking among the youngest subjects and therefore preventing them seeing a rigid motion event at slow rates of presentation, is evidently unnecessary to the perception of the event as rotation at fast rates.

A conclusion might have been drawn from our data, then, that only when changes take place "too slowly" (or, perhaps in other situations, "too quickly") does previous experience determine how those changes will be seen - as what kind of events. Focussing on slow rates of change, then, the aim of Experiment II was to investigate the effect

of immediately previous experience on whether a slow rate presentation, seen earlier as an expansion, would be seen again as an expansion or, newly, as a rotation. In fact, in our experimental situation the role of immediately previous experience proved to be minimal.

Whereas we had expected to find greater shifts in response to the last slow presentation rate in condition IIB (slow/fast/slow) than in IIA (slow/slow/slow), and that changes in response in condition IIB would be significantly greater among older subjects than among younger ones, these trends did not emerge. In comparing first and last responses to 1 rpm presentation, there were indeed greater shifts among responses of older subjects in general, when compared with age group I. This was true in both conditions of Experiment II as well as when the whole sequence of five rate presentations in Experiment I is considered. The relatively greater tendency of older subjects to change responses seems to be attributable to actual differences in percepts, rather than to differing degrees of intransigence in response behavior since Age Group I subjects in Experiment IIB in fact changed their responses <u>back</u> to what they had originally seen on the first presentation of 1 rpm, in spite of having given an intervening rotation (B) response, more often than older subjects. This would seem to indicate that the youngest subjects were less influenced by their immediately previous response or perhaps less influenced by having seen rotation (in Experiment IIB), and that their percepts of the same visual information change less than do those of older subjects, when the phenomenon is experienced repeatedly. The shifts that did occur in responses (in Experiment IIA) as a function of repetition were no

greater and no less than the shifts that occurred when the slow rate presentation was seen again _after_ an experience of rotation (in Experiment IIB). The effect of having seen the rotation immediately previously was not noticeable in the subsequent response to the repetition of the slow rate presentation.

These findings are in disagreement with Wallach, O'Connell and Neisser's claim that a previous perceptual experience of a phenomenon as a rigid motion event will cause subsequent similar presentations, even if stationary, to look three dimensional and rigid (Wallach, O'Connell and Neisser, 1953). In fact, in the "slow/fast/slow" condition, having seen a given presentation as a rigid motion event (at a fast rate) subjects often _did_ go back to seeing nonrigid motion (E) or some combination (B) of rigid and nonrigid motion simultaneously, when shown a slow rate presentation again. This tendency was stronger, though not significantly, among the youngest subjects.

The present findings also seem to contradict Neisser's more recent idea that information already acquired creates expectancies or "anticipatory scemata" that direct active search and create a "readiness" that determines what information will be picked up next (Neisser, 1976). E. Gibson, also, (E. Gibson, 1969, p. 213) might have predicted that having once seen the transformational invariant (that is, a perspective transformation, a "turning" type of change) this same invariant will be detected and responded to in following presentations even at very slow rates of change. In fact, in our study older subjects gave non-rotational responses just as often _after_ having seen a rotation event (in Experiment IIB) as they did when they had seen only the very same slow rate presentation again and again (in Experiment IIA). This

implies that whatever learning occurred from "having seen" the transformational invariant, is no less or more than that which comes with greater differentiation as a function of repeated exposure.

Explanations based on developmental changes in the ability to see geometrical sources of information. Johansson's suggestion that there may be an "ontogenetic development of perception of motion and form changes" (Johansson, 1964, p. 192) seems to be confirmed by our study. Vurpillot, among others (Meili and Tober, 1931) has documented how slow a child's rate of perceptual processing is on the one hand, and, on the other hand, how limited the capacity for integrating information; "Information which can be combined or organized must be close together in space and time" (Vurpillot, 1976, p. 322).

Apart from Johansson's own study with only a few 10 and 11 year olds (Johansson, 1950) Carpenter's study (1974) seems to be the only previous formal investigation of a kinetic depth phenomenon which included children. Carpenter was interested in whether children and adults would see the same one or two dimensional cues as specifying depth, whether children need "more" cues than adults or different ones to see depth.

Carpenter's subjects saw a line of dots, apparently rotating in depth and were asked to judge the direction of the rotation. He was interested in the relative velocities or accelerations of different points on the line, as they might relate to judgements of changing orientations in depth. He used a rate of 3 rpm or 18 degrees of arc per second (the rotation was a complete 360 degrees). (In the present

study, the slowest rate presentation was 1 rpm for an oscillation cycle of 180 degrees, 90 degrees to each side, back and forth, or 3 degrees of arc per second. Carpenter's rate of 18 degrees per second corresponded to our 6 rpm presentation.) Carpenter's youngest subjects (6 years old) performed at chance on all stimuli including the standard projection which incorporated all the cues. "This strongly suggests that no unconditional stimulus exists in the one dimensional transformations employed" (Carpenter, 1974, p. 67). He suggested, also on the basis of these results, that the young subjects had perhaps failed to see any depth in the displays to begin with. Carpenter posited, then, that "perhaps no unconditional cue exists even in two dimensional transformations" (for direction of rotation) (Carpenter, 1974, p. 69).

It would have been extremely interesting in light of the present study to know more about the events actually perceived by Carpenter's youngest subjects (who could not tell the direction of rotation and seemed not to see any depth): what was it they _were_ seeing? Was it some two dimensional transformation, a size change, or curvilinear change of the line, and therefore a different _kind_ of event?

Braunstein (1976) has suggested what might be unconditional cues in the second dimension when he claims that changes in the projected angle between vertical and horizontal contours are the principle mediators of veridical rotation in depth. Bower's infant studies (1964, 1965) and the present study attest to the fact that young children do see depth from two dimensional displays very early. However the present study seems to indicate that there are no unconditional cues whether in terms of contour angles or any other geometrical aspect

of a two dimensional display. In fact it seems the very same changes in the angle between contours seem to describe an event in depth at one rate of change and a flat, two dimensional distortion of shape at another rate of change. Further, it seems that even the rate of change _in conjunction_ with a two dimensional cue would not be an "unconditional" cue for depth to observers of _all_ ages, but that the rate of change which will _always_ specify a rigid motion in depth event to observers, must be faster (in our situation) with younger observers.

Developmental Changes in Spatial Representation Systems. A basic question had been, following Piagetian thought, whether pre-operational children would ever see the "degraded" information for rigid motion in the shadow phenomenon. We wondered, would it always appear to these young children as a two dimensional shape change because, after all, they had no "notions" of groups of spatial transformations (e.g., perspective transformations) to guide the gathering and "decoding" of visual information or to subordinate the changes in configuration to the perspective transformation (Piaget, 1969, p. 359). Moreover, if imagery were involved in the perception of the shadow as a rigid motion as Shepard and Judd (1976) might suggest, our youngest subjects who would not, according to Piaget, have images of movement or perspective transformations, would not have seen the phenomenon as a rotation, no matter what the rate of presentation.

What was striking in the present study was that at the fastest rate of change nearly all subjects, even 85% of the youngest age group, saw an unequivocal rotation event. At fast presentation rates, to respond to the Piagetian train of thought, (even in our context of "degraded"

visual information) it seems no "completion" or "correction" of the perceptual information is necessary (Piaget, 1969, p. 360) and no "decoding of the perceptual messages from a figurative form" by integration into a notional system of transformations, as Piaget might claim (Piaget, 1969, p. 359) is required for the phenomenon to be seen as a perspective transformation, an event in which something turns.

Two Possible Models

Let us offer then another approach to an explanation of our finding that there are rate dependencies in the perception of rigid motion that lead to minimal developmental differences at fast speeds (where rigid motion is universally detected) and marked developmental differences at slower speeds (where older subjects tend more readily to "see" rigid motion).

Let us assume at the outset that the Gibsonian position is in fact true, i.e., that event structures are indeed specified by stimulus transformations. Let us further assume that with transformations specifying a complex event there is a marked "detection problem" where the perceptual system must function with some minimal amount of efficiency in order to "read" the event specifying stimulus transformations. Let us further assume, with Gibson, that:

> The flow of ecological events consists of natural units that are 'nested' within one another. There are episodes within episodes, subordinate ones and superordinate ones....Episodes like surfaces are structured at various levels.
>
> Gibson (in preparation, p. 13)

While the present study does not deal with ecological events of the sort to which Gibson refers in the preceding quote, the notion of nested events may be of use in accounting for our data.

It is quite possible that the slow rates of presentation utilized in our studies interfered in some manner with pick up of information regarding stimulus transformations that specify rigid motion. One way in which this could occur would be if there were some temporal limitation on visual processing and that the pick up of transformations were in some way bounded within temporal limits. Thus, the information that could specify an external event, if it occured within the boundaries of this hypothetical temporal unit, would accurately and completely be detected as a total event. However, if the information rate was too slow to occur within this unit, some nested portion of that event would be picked up and a different event specified (to the observer) or, as shall be argued later, the event remains "less specified" in some way. The "complete" event could, under these conditions still be specified, but that specification would depend upon either some process which could "stretch" the temporal unit, or which could integrate information across temporal units which maintain their size.

Stretching of perceptual units has been speculated on by E. Gibson, who has raised questions concerning the size of temporal units as a developmental phenomenon (E. Gibson, 1969, p. 381). It is quite possible then that the developmental findings of this study could be accounted for by a theoretical assumption that the size of temporal processing units increases with age, so that more complex event specifying stimulus transformations could be directly perceived. Of course the alternative

view is that some temporal integration process (across temporal units of more or less constant size) cannot at this point be rejected. This view, consistent with the position of Piaget (1969), would perhaps provide a resolution to our quandary in terms of developmental increases of perceptual activities leading to temporal integration and the availability of representational structures which could subordinate and unite independent subspecifications.

Piaget states, "*where perception requires perceptual activity*, we see only what we think of looking for" (Piaget, 1969, p. 349, italics mine). If this idea is at all accurate it would lead us to the idea that at fast rates of change, our phenomenon requires little perceptual activity beyond what Piaget might call initial centrations. (An interesting observation in the context of our study, then, is the extent to which older subjects, supposedly capable of "systematic decentration" also are prone to see expansion at slow rates of presentation.) The developmental differences we see only at slow rates would be explained by the notion that the temporal compactness or drawn-outness of an event might require differential perceptual activity.

The general form that *either* of these positions takes is that at fast presentation rates sufficient information can be detected to completely specify an event, while at slower rates other processes, possibly uniting information encountered over time, must be utilized. If developmental differences occurred for the latter processes but not for the former, our pattern of results would be generated.

Moving now from the general form of the argument to the more specific question of the sort of temporal process that might be involved

we can examine hitherto undiscussed portions of our data, viz. data on latencies and on responses to countersuggestions, after fast and slow rate presentations.

If the amount of information needed to specify the rigid motion event had, as shown, little to do with the total time the transformation was watched, we may speculate then that the rate dependency of event perception involves not how much information is seen, but how much is seen per unit time. Faster rates give more information about the transformation per unit time. Slower rates of change give less information per unit time, no matter how long an observer watches. When an observer sees a complex transformation as in the present study, i. e., non-linear and therefore the full transformation is not "predictable" from any small part of it (e.g., as a ballistic path of movement would be), a minimum amount of the transformation must be experienced for it to specify a rigid motion event. This minimum amount of information per unit time is experienced, obviously, at fast rate presentations. At slower rate presentations, also, it is generally experienced by older subjects, but not by younger ones. Is there, then, any relationship between the response times of older subjects at slower rate presentations and the minimum amount of information per unit time to specify rotation?

At 2 rpm where most of the older two age group subjects already saw rotation, each cycle took 30 seconds. If the half cycle (i.e., the point of turning back in the oscillation) was the important information about rigid motion, this would have taken 15 seconds to see. In fact, no age group had a mean latency of response that was this long. (Here, it should be pointed out, that in the present study there was no control

over which portion of the cycle would be seen first so that, in fact, the "turning point," if crucial, might have occurred just after or only 15 seconds after the presentation began. From the present study we have no precise information about which part of the cycle the subject saw and therefore no idea about whether there is a "crucial" portion of the cycle that gives geometrically-specifiable information for rigid motion, i.e., a turning-back point). However, that response times at 2 rpm were not significantly different from those at 1, 3 or 6 rpm for these older age groups and that there was no significant difference between response times for E, B, or R responses, does seem to indicate that responses were not made on the basis of having seen a certain number of cycles. However it is clear that although there were no significant age differences in response times, older subjects did seem to detect "enough" information per unit time to see a rigid motion event at much slower rates of presentation, whereas younger subjects did not. On the other hand, the 15 rpm rate, (a four second cycle) afforded subjects of all ages "enough" information per unit time for the detection of rigid motion.

The latency analyses however must maintain a somewhat indeterminate status with respect to our question. This is for basically three reasons. First, latencies do not reflect "processing time" alone. Some portion of the latency to response has to do with decision criteria as well. As shown, also by our data, latency is quite sensitive to manipulations which serve to put the subject into "doubt." Thus, the latency for presentation 1 R (after subjects' judgements have been challenged at 15 CS) is much longer than for any other presentation.

A second reason for not putting too much reliance on latency data is that we have an, as yet, incomplete specification of the minimal amount of information (in geometrical terms) which will uniquely specify the sort of event looked at here. A more effective use of latency data (should we be able to gain some control over the decision time component of the measure) could be made if there were sufficient information concerning the actual transformation encountered in some unit of time.

A third reason for doubt relates to the point made above. Equipment limitations did not allow us to have sufficient control over the precise starting place of the moving stimulus when it was first encountered. Our only control was in assuring that the stimulus was not in a frontal position at the point of initial encounter. It may very well be the case (and this our latency data, to the extent believable, points us toward) is that some portion of the information within a complete cycle is sufficient for stimulus specification. Since we do not yet know the critical portion (for the second reason given above) we have no way of specifying when it was encountered, and hence its relationship to response latency. Some likely candidates at present might be the information obtained when the stimulus does indeed reach a "frontal" position, or the information obtained when it reaches the end of a cycle and the transformation reverses.

Given this degree of uncertainty, it is probably best to phrase our arguments concerning temporal limitations in terms of the relative probabilities, at different rates, of encountering critical information points. Thus, faster speeds, in that they expose the subject to more stimulation per unit time, will therefore increase the probability of

encountering a critical information point (should there be such points).

Ambiguity of the Event at Slow Rates

Pursuing this line of reasoning we attempted to gain measures of the subjects' certainty, or lack of it, in making statements concerning the events perceived. If there is a firm stimulus determination of the perceived event we expected that subjects would be resistant to countersuggestions about the nature of the stimulus casting the shadow. If there was uncertainty (and hence some degree of stimulus undetermination) we might expect that countersuggestion would lead to some instability in the subjects' judgements.

The results obtained are in accord with a two state interpretation such as that proposed above. At 15 CS, where maximal stimulus information per unit time is presented, subjects of all ages showed judgments of rigid motion in depth and were resistant to countersuggestion; 88% of all responses were reaffirmed in response to a countersuggestion, and there were no developmental differences in this percentage. At 1 CS where there would be expected to be minimal stimulus determination, uncertainty was considerably higher; only 39% of the responses were resistant to countersuggestion.

Thus far, it would seem as though the uncertainty of judgement was directly related to the amount of stimulus specification (as hypothesized by a rate dependent temporal processing model). Certainty judgements, as measured by response to countersuggestion were further examined in terms of age effects and by response category, in order to gain further insight into the issues of developmental change, on the

one hand, and the hypothesis of partial stimulus specification on the other.

Taking the latter first, it could be argued that if there were in fact partial determinations of nested events at slow rates, then certainty of judgement should be unrelated to response category (e.g., rigid motion; expansion; or a combination). Some portion of the stimulus transformation might serve to specify either. An examination of resistance to countersuggestion 1 CS by category of exclusive response (categories 1, 5 and 7) yields the following pattern which for purposes of exposition is here presented in tabular form:

Table 12

Percentage of Resistance to Countersuggestion 1CS by Category of Response to Repetition of 1 rpm (Experiments I and II Combined)

Expansion	Both	Rigid Motion
26.8%	41.5%	46.3%

It is clear from this table that the overall low percentage of resistance to countersuggestion at 1 rpm cannot simply be accounted for in terms of some category of response (e.g., expansion) being well specified at this rate while the others were not. In fact, expansion seems to be least specified (by this sort of analysis).

Examination of the data by age could further outline the implications of the rate-dependent model. If the model were limited to age changes in the proportion of stimulation encountered and integrated into events, we would have expected that age changes in the efficiency of temporal integration processes would lead to greater certainty of judgements as age increased and more information was processed. The data are presented below:

Table 13

Age Differences in Percentage of Resistance to Countersuggestion 1CS (in Experiments I and II)

Age Group			
4 ÷ 5	8 - 9	12-13	Adults
65.0%	40.0%	30.0%	22.5%

In fact, this comparison shows that subjects in the youngest age group were significantly more resistant to countersuggestion at 1CS than each of the other age groups. When the youngest group is compared with the other age groups combined, this difference is significant at $p < .001$ (χ^2=13.27). The two younger age groups, taken together, were significantly more resistant than the two older age groups (χ^2=10.47, $p < .01$).

What is particularly interesting about the data presented in this table is that the data is the reverse of what might have been expected from either the rate-dependent model for which we are seeking support, or from the standard findings in Piagetian concrete operational tests where resistance to countersuggestion is used as an index of the strength of a cognitive structure. Since strength of cognitive structures is expected to increase rather than to decrease with age the finding of a decrease in resistance to countersuggestion is a rather striking and, at first, puzzling finding.

We believe that this backwards finding points to an important aspect of the study that has heretofore gone unmentioned. In some real sense the presentation of a stimulus transformation at very slow rates of speed creates a situation of considerable ambiguity. To begin with stimulus conditions are reduced from their conditions of normal encounter. We seldom encounter the world as a set of shadows

cast upon a window shade (Plato notwithstanding). Nor do we normally encounter perspective transformations occurring at the slowness that they have been presented here -- for purposes of analysis. Thus, in many important senses we have violated conditions of ecological normality. In doing so it is probable that a situation of considerable ambiguity has been established. Previous research by Fein (1972) has demonstrated that judgements which reflect ambiguity are more characteristic of older subjects, in truly ambiguous situations.

Stated in terms of signal detection theory (Swets, 1964), then, it seems that older subjects are more likely to shift judgement criteria and to see an ambiguous stimulus in several ways. (The advantage, here, of the countersuggestion technique is that it affords us more information about the various, even simultaneous, criteria applied for the different perceptual judgements of the ambiguous stimulus.)

Thus, the developmental data with respect to resistance to countersuggestion suggests that an important feature of our experiment was that it in fact violated ecologically normal situations and created ambiguity. Sufficient stimulus specification, at fast rates of presentation, either was more in accord with ecologically normal rates of change for a rigid motion event, or provided sufficient stimulus information to reduce ambiguity. However, at slow rates of change, ecologically normal rates of change are violated and sufficient stimulus information per unit of time is denied. Thus, some new class of processes, elicited in non-normal situations and in a condition of informational deprivation (at slow rates) is invoked by subjects in this experiment.

Michotte, experimenting with manipulations of the speeds of objects

in the Launching and Entraining Effects, described adults' perceptions of an ambiguous event, "the formation of a hybrid and ephemeral perceptual structure in which both tendencies are found" (Michotte, 1963, p. 345). He stated that "the existence of a range of speeds particularly favourable to the Launching Effect is easy to understand, provided we admit the hypothesis, which seems forced upon us, that speed acts as a factor of integration"(Michotte, 1963, 107). To generalize from Michotte, then, when the rate of an event is outside of the "range of speeds particularly favourable" for that kind of event, additional processes seem to be called forth where (developmentally) available, or else the change is seen as an altogether different kind of event. The idea that there may be an ecologically "normal" range must be sandwiched, then, between an idea of a range of rates at which a particular kind of event "normally" occurs and also a range of rates "normal" for the detection mechanism (Shepard and Judd, 1976). It seems then that with development additional processes become available for the detection of events that are faster than "normal" (Meili and Tobler, 1931; Piaget, 1969) or slower than "normal" (the present study).

We have, at present, insufficient information to specify in great detail what these additional processes are. Some of the previously rejected positions may in fact apply -- but, our data clearly show -- only in conditions of constructed ambiguity.

Thus, it may, in fact be the case that adults do need fewer cues to detect three dimensional motion as Carpenter (1974) posits, or that a "preference" for seeing rigid motion (Johansson, 1975) is evidenced among adults, but only when stimulus information is initially degraded. Similarly, it may be the case that the older subjects' greater

knowledge of the world might enable them to see more possible sources of the shadows cast than the younger subjects, but only when stimulus determination has been temporally reduced. Similarly, cognitive processes having to do with "figural knowledge" (Piaget, 1969) may be involved, particularly in terms of response to the suggestions about alternative specifications implied by the countersuggestion technique or internal assimilations of information to conceptual categories, but again, only at abnormally slow rates of stimulus change in a shadow world.

Whatever "additional" or "developmentally differential" ingredients might be speculated to be involved in the detection of changes when they are considerably slowed down, it is apparent that even (or perhaps especially) within this shadow world, the rate at which the transformation takes place is (as Michotte, 1963, asserted) a crucial determinant of what event will be seen.

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