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**THE EFFECT OF STIMULUS COMPLEXITY AND AMOUNT OF FAMILIARIZATION  
ON INFANTS' PREFERENCE FOR NOVEL AND FAMILIAR STIMULI**

by

**Michael A. Hunter**

**B.A. (Hons.), Simon Fraser University, 1975**

**M.A., University of Waterloo, 1978**

**THESIS SUBMITTED IN PARTIAL FULFILLMENT OF  
THE REQUIREMENTS FOR THE DEGREE OF**

**DOCTOR OF PHILOSOPHY**

**in the Department**

**of**

**Psychology**



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## ABSTRACT

The research comprising this dissertation was designed to investigate the effects of stimulus complexity and prior experience on preferences for novel and familiar stimuli in 8-month-old and 12-month-old infants. The hypothesis was that infants who had habituated to either a relatively complex or a relatively simple array of toys would subsequently spend more time exploring novel toys than would infants who were familiarized but interrupted prior to habituation. A further prediction was that habituated infants would show a significant preference for novel toys rather than for familiar toys in both simple and complex conditions, while interrupted infants would show a significant preference for a familiar toy array when it was complex. When the array was simple, interrupted infants were predicted to show no preference for either novel or familiar toys. Finally, the complexity of the stimuli was hypothesized to vary according to age such that an array that was simple for 12-month-olds would produce results consistent with its being complex for 8-month-olds.

The 12-month-olds were familiarized with an array containing either 5 toys (complex) or 3 toys (simple). Only a 3 toy array was available for the 8-month-olds. Following familiarization a test trial was run in which half of the infants in each of the familiarization groups received the

familiar array in the same location as during the familiarization trial and a novel array in a novel location. For the other half, the familiar array was moved to a novel location and the novel array placed in the familiar location. Two measures of exploratory behavior, visual attention and focused manipulation, were recorded.

The results indicated that regardless of age and complexity the habituated infants spent more time exploring novel toys than did the infants who were interrupted prior to habituation. On focused manipulation, habituated infants also showed an overall preference for novel toys, while only those interrupted infants who had been familiarized with a complex stimulus preferred familiar toys. No preference for either novel or familiar toys was found for infants who were interrupted with a simple stimulus. Consistent with the hypothesis that complexity is an age-related variable, the results for the 8-month-olds contrasted with those found for the 12-month-olds who had been familiarized with a same sized array (3 toys) and were comparable to those found for 12-month-olds who had been familiarized with a more complex array (5 toys).

The location of the toys had no effect on the exploratory behavior of any of the habituated groups, nor did it affect the 12-month-olds who had been interrupted with a simple array. The exploration of interrupted 8-month-olds and 12-month-olds who had been interrupted with a complex array, however, was affected

by location. Both of these groups returned more often to the familiar toys and continued to explore them throughout most of the test trial when those toys remained in the familiar location. When the familiar toys had been moved to a novel location, however, the 8-month-olds initially chose at random which array to explore, then either stayed to explore if they had chosen the familiar toys or left to find the familiar toys if they had chosen the novel toys. Twelve-month-olds in this condition consistently returned to the familiar location, briefly examined the novel toys, then proceeded to the novel location to resume exploring the familiar toys. The results of this study provide empirical evidence for Berlyne's (1960) view that infants explore in an orderly manner with the purpose of learning about the objects in their environment. They do not haphazardly look at and handle objects, but do so successively as the properties of each become assimilated. If this process is interrupted they will return to resume exploration and complete learning before moving on to explore new things.



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P

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## I. Introduction

This thesis is an investigation of some of the determinants of exploratory behavior. More specifically it is an investigation of visual exploration and focused manipulation in eight and twelve-month-old infants to stimuli varying in location, complexity, and novelty. This chapter is a review of the relevant literature.

### Review of Theories of Exploratory Behavior

A plethora of theoretical viewpoints have been advanced to account for the empirical findings from studies of exploratory behavior. The major viewpoints, which include earlier drive formulations and the more recent optimal-arousal and information-processing (optimal-incongruity) positions, are presented below.

#### Drive-Theory Accounts

Motivational theorists were perplexed by the laboratory findings of exploratory behavior. The early studies by Dashiell (1925), Mote and Finger (1942), Nissen (1930), Tolman (1925) and Harlow and his colleagues (Harlow, 1950; Harlow, Blazek and

McClearn, 1956; Harlow, Harlow and Meyer, 1950) had demonstrated that exploratory behavior would occur in the absence of identifiable primary drives such as hunger and thirst, and that learning would actually accrue when the only specifiable rewards were those of problem solving or continued commerce with a novel stimulus. How was this apparently intrinsically motivated behavior to be accounted for? Some psychologists attempted to explain exploratory phenomena by postulating new drives such as an "exploratory drive" (Butler, 1953; Montgomery, 1951), a "boredom drive" (Isaac, 1962; Myers and Miller, 1954) and a "manipulative drive" (Harlow, 1950). According to O'Connell (1965), the proponents of these positions can be categorized as either "tedium" or "titillation" theorists. Tedium theorists stressed that monotonous circumstances motivate the organism to explore in order to alleviate boredom (i.e., drive induced by the lack of a stimulus). Titillation theorists, on the other hand, emphasized the role that variables such as novelty and complexity play in eliciting exploratory behavior (i.e., drive induced by the presence of a stimulus).

Each theoretical approach seemed incomplete. Tedium theorists ignored the role of novelty and complexity while titillation theorists dismissed the relevance of satiation and boredom effects. These positions were open to other criticisms. To Hunt (1963), the mere naming of new drives offered no explanation of the behavior and seemed only too reminiscent of

McDougall's practice of naming instincts.

White (1959) made a more detailed criticism of the drive-naming approach. He began by saying that if exploratory behavior is to be considered motivated by a drive, that drive must have the same functional properties as the established drives such as hunger, thirst and sex. According to this traditional view, drives involve (1) a deficit or need in body tissues outside the nervous system which (2) energizes or induces behavior that (3) results in a consummatory response which (4) reduces the need or deficit and (5) produces learning.

White then demonstrated that an "exploratory drive" does not fit this definition. It does not appear to be correlated with any non-nervous-system deficit so no tissue need can provide the stimulus for behavior, nor is there an appropriate consummatory response to the behavior the drive presumably induced. True, the exploration of a particular object can become satiated and this may be considered a consummatory response. However, even if the definition of a consummatory response is loosened to allow for satiation another more serious problem immediately arises. Since satiation seems to occur only in accordance with learning about the properties of the object of exploration (e.g., learning to solve mechanical puzzles, Harlow, 1950), learning in effect produces a reduction in exploratory drive rather than a reduction in exploratory drive producing learning. Such a possibility would be anathema to traditional

drive reduction theory.

White also noted that the reinforcement provided by exploratory behavior to strengthen other responses does not seem to involve need reduction. White cited the work of Montgomery (1954) to show that animals often make choices that increase rather than decrease the exploratory drive. If the exploratory drive is instigated by a novel stimulus, as Montgomery and other titillation theorists suggest, then one would expect an avoidance of novel stimuli since these would increase rather than decrease the drive. Yet, just the opposite is true: stimuli which by the drive account would increase exploratory drive are sought rather than avoided. The occurrence of responses that induce a drive rather than reduce it would be unacceptable to traditional drive theory. Along a similar vein of criticism, Brown (1961) adverted to the problem of attributing both drive-inducing and reinforcing properties to such stimulus properties as novelty and complexity. Commenting on the exploratory-reward studies with monkeys (e.g., Harlow, 1953) Brown pointed out:

If the act of looking out the window at the outside (laboratory) world is the specific event that arouses visual exploration, then the monkeys do not have the drive until after they have succeeded in opening the correct window. The drive aroused by the final act cannot, therefore, provide the impetus for the response of window opening (1961, pp. 336-337).

Finally, White criticized the possibility that exploration is instigated by a "boredom drive". If boredom causes exploration, then the reinforcement for exploratory behavior is the thing which returns the organism to a state of boredom. White stated "It is distinctly implausible to connect reinforcement with the waning of an agreeable interest in the environment or with a general progress from zestful alertness to boredom" (1959, p.302).

Prompted by these difficulties, new theoretical arguments have been advanced that would account for intrinsically motivated behavior such as exploratory behavior. The two most prominent viewpoints are the optimal-arousal and information-processing theories. These positions are both cognitive approaches to motivation and behavior and stand in direct contradiction to the mechanistic drive approaches. They assert that behavior is engaged in voluntarily as a result of information provided both by internal sources of stimulation (e.g., proprioceptive stimuli and memory) and by cognitive interpretations of external sources of stimulation. A fuller description of these theories is given below.

### Optimal-arousal Theories

In the mid 1950's and early 1960's several writers adduced the position that the organism's physiological state of arousal provided the motivation undergirding behavior (Hebb, 1955; Fiske and Maddi, 1961; Leuba, 1955; and also Hunter, 1978 for a more complete review). The general proposition was that behavioral efficiency increases from a low point when arousal is low, to a high point at an intermediate level of arousal, only to decline again as arousal increases still further. Thus, organisms are motivated to engage in behaviors (such as exploratory behavior) that lead them toward an optimal level of arousal and, depending on the organism's present state of arousal, either increases or decreases in arousal may reinforce learning. A minor but potentially important addition to this general proposal came from Fiske and Maddi (1961) who argued that the optimal level of arousal is a continuous variable and is a function of the organism's sleep-wakefulness cycle.

### Information-processing Theories

Optimal-arousal theorists have anchored motivation to physiological conditions. Many others have rejected this trend, however, and preferred to view the motivation for exploratory behavior as inherent in information processing per se (Dember

and Earl, 1957; Glanzer, 1958; Hunt, 1963, 1965; McReynolds, 1960). Different information processing theories of exploratory behavior concur in the belief that (a) organisms are to be viewed as information processing systems, that (b) information is synonymous with uncertainty in the environment, and that (c) there is an optimal level of uncertainty that provides the motivation for exploration. Given alternatives representing different levels of uncertainty, they predict that an organism will choose (explore) that alternative which is closest to its optimal level of uncertainty.

The central thesis of the model proposed by Dember and Earl (1957) is that exploratory behavior is jointly determined by the complexity of the immediate stimulus environment (which in their terms is a concept identical to information) and the psychological complexity of the organism (i.e., expectations based on previous information processing by the organism and on current information processing capabilities). The individual is said to have an optimal level of psychological complexity. Stimuli slightly more complex than the optimal level of the organism, denoted "pacer stimuli", attract attention, which in Dember and Earl's theory is used to refer to all behavior which brings the organism into contact with the environment. Although they do not elucidate the mechanism of behavioral modifiability involved, they do suggest that continued commerce with pacer stimuli causes the optimal level to shift upwards; thus, any

change in exploratory interest is hypothesized to move from the less complex to the more complex (1957). Somewhat similar theoretical viewpoints have been advanced by Glanzer (1958) and by McReynolds (1960). Rather than an optimal level of psychological complexity, however, Glanzer (1958) refers to an optimal amount of information per unit time, while McReynolds (1960) describes an optimal perceptualization rate.

\* Hunt (1963, 1965) incorporated the notion of optimal incongruity (where incongruity is similar to uncertainty as it exists in such stimulus properties as novelty and complexity) into a general theory of motivation. In outlining his theory, Hunt (1965) enumerated and provided answers to several critical motivational questions of relevance to exploratory behavior.

The first was the instigation question "What initiates behavior?". Hunt answered the question within the framework of the feedback loop as conceptualized by Miller, Galanter and Pribram (1960). Their model is called the TOTE unit, which stands for Test, Operate, Test, Exit. Within the TOTE unit there is a mechanism which compares input to some standard such as an adaption level, an expectation, etc. When there is an incongruity between the input stimulus and the standard of comparison the organism will be motivated to behave, that is, it will in some way operate to reduce the incongruity. The operating will continue so long as the incongruity exists. However, when there is finally a congruity between stimulus and



standard, the operation will terminate and the organism will be freed of the process. Thus, in answering the initiation question Hunt also answered the termination question: When incongruity is lost by information processing, a stimulus is no longer intrinsically motivating and will no longer elicit or maintain exploration.

The next question Hunt dealt with was energization, "What is it that provides the energy for an organism to engage in exploration?". The answer to this question also centered on the notion of incongruity, and Hunt quite simply postulated that information processing or uncertainty reduction by itself is motivating.

Another motivational question that Hunt considered was what he called the "direction-hedonic" question. "Toward what, and away from what, will an organism move?". In answering this question Hunt proposed the central hypothesis in his theoretical position; namely that organisms need an optimal amount of uncertainty or incongruity and will seek out those situations that provide them with that optimum. When there is insufficient incongruity, they will approach situations which provide more (up to the optimum) and avoid situations which provide less. So also, if one is overstimulated by incongruity, situations that afford less incongruity will be approached and those affording more, avoided. The optimal level of incongruity is also suggested by Hunt to be a special, and in general, overriding

standard against which all incoming incongruities are compared within the TOTE unit.

To summarize, Hunt's theory states that the motivation for exploratory behavior resides in the informational interaction between organism and circumstance. It is initiated by some incongruity between an input and some standard where the standard can be an adaptation level, an expectation or simply input from the previous moment, but where the overriding standard is an optimal level of incongruity. It is the reduction of incongruity that leads to learning about the object of exploration, and the "need" for an optimal level of incongruity that leads to stimulus seeking and stimulus avoidance (and which may serve to reinforce other responses). In Hunt's words:

The hypothesis of an optimal standard of incongruity supplies a motivation for behavior change and learning that is inherent within the organism's informational interaction with its circumstances: inherent within seeing and hearing. Repeated encounters with given organizations of input lead to adaptation... This fact that repeatedly encountered organizations of input become subjectively passe prompts organisms to turn away from unchanging circumstances to those providing moderate degrees of incongruity. This supplies an explanatory interpretation of both exploratory and manipulative behavior (1965, p.227)

Theories incorporating both Optimal-arousal and Information-processing

Most theorists interested in intrinsic motivation and exploratory behavior have attempted a choice between optimal arousal and information processing (optimal incongruity) as dictators of the direction of exploration. However, Walker (1964, 1973) and Berlyne (1960, 1967, 1969) have incorporated both.

Walker's theory (1964, 1973) has much in common with the positions of Hunt (1965) and Fiske and Maddi (1961). He agrees with Hunt that the motivational basis for exploration inheres in information, although where Hunt refers to the processing mechanism as adaptation, Walker prefers habituation. Also, for Walker the construct governing stimulus selection is optimal complexity, a construct recognized by Hunt as closely related to optimal incongruity (cf. Hunt, 1965, p. 219).

Walker defined optimal complexity as the "degree of psychological complexity the organism will seek to maintain" (1964, p. 56), where psychological complexity depends upon (a) the complexity of the stimulus initiating the event, (b) the frequency of the past occurrences of the event, (c) selective readiness for the event, and (d) the arousal value of the event. Unlike Hunt, Walker recognized arousal level which "serves to modulate the psychological complexity of a psychological event.

An event that occurs when the organism is in a high arousal state will be more complex than a similar event occurring during a state of low arousal" (1973, p. 72). A second property of arousal is its effect on intraindividual variations in optimal complexity level, particularly via diurnal variation. Hence, like Fiske and Maddi (1961), Walker's optimal level construct varies with the sleep-wakefulness cycle of the organism.

According to Walker, organisms presented with a number of events that differ in psychological complexity will select the one closest to the optimum. As the event occurs it produces a sharp rise in complexity (due to arousal increase, later (1973) referred to as sensitization) followed by a fall to a level below the optimum (due to habituation). This compels selection of another event of sufficient complexity to reinstate the optimum. This process eventuated in a restless exploring organism.

Even more than Walker, Berlyne (1960, 1967, 1969) incorporated ideas central to both optimal arousal and optimal incongruity position into his theory of exploratory behavior.

Berlyne's early work (e.g., 1950, 1955, 1960) concentrated on the rewarding properties of drive reduction. He considered arousal to be a general drive state and concluded that behaviors which reduced this would be reinforced. Exploration could serve to reduce arousal through familiarizing the organism with a novel stimulus. Later (1967, 1969), however, Berlyne also

recognized that increases in arousal can be rewarding.

Berlyne claimed that exploration can be explained physiologically with two sets of reasons. Both have to do with the needs of the brain and the fact that the human organism is primarily an information processing system that uses information from the environment and its memory to make choices. First, since there is always spontaneous activity in the central nervous system, and since this activity can underline many different responses, it is important for the organism's survival to select adaptively from among the myriad of possible behaviors. Second, organisms are "designed to cope with environments that produce a certain rate of influx of stimulation that taxes the nervous system to the right extent, when naturally occurring stimuli are either too easy or too difficult to assimilate" (Berlyne, 1966, p.26).

In the course of normal information processing the organism must compare and contrast various stimuli from the environment or memory in order to note differences and similarities. It must also categorize these elements into a meaningful system for operating and storing. Berlyne referred to these processes as collation and pointed out that things like novelty, complexity, incongruity, etc., all involve collation of stimuli from the environment and memory.

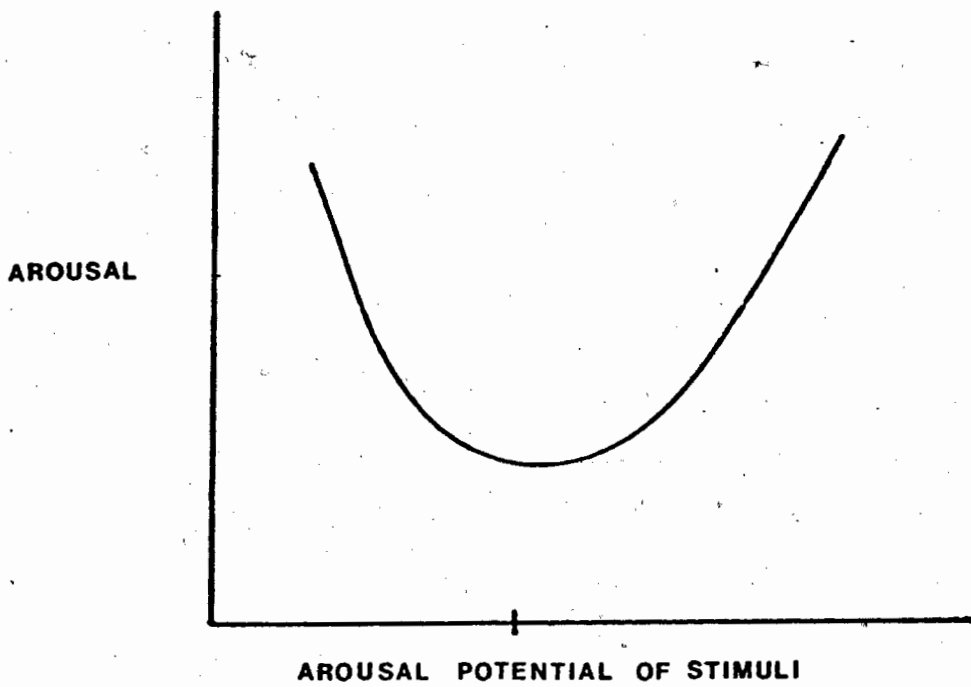
Collative stimulus properties hold what Berlyne (1960) called arousal potential. Berlyne suggested that stimuli which

offer an optimum of arousal potential are approached, thereby implying that people require an optimum of stimulation. His discussion of the relation between arousal and arousal potential stated that when arousal potential is either below or above the optimum, arousal increases and motivates either stimulus seeking (low arousal potential) or information reduction (high arousal potential). The relationship, then, between arousal potential and arousal approximates a U-shaped function. This relationship, derived by Berlyne (1960) and depicted by Hunt (1965, 1971) appears in figure 1. Berlyne was obviously operating within a drive-reduction framework as of 1960. Although he maintained that organisms seek an optimal level of arousal potential in this environment, this seeking was always motivated by a reduction of their own arousal levels.

Later Berlyne (1967, 1971, 1973) developed a system to account for the findings that increases as well as decreases in arousal can be rewarding. He talked about the correspondence between arousal potential and arousal increments, and pointed out (1973) that arousal or arousal level must be distinguished from changes in arousal level (i.e., arousal increments or decrements). Berlyne's position was that there is a relationship between arousal change and hedonic value (i.e., preference) such that both a decrement in excessive arousal level and a moderate increment in deficient arousal level have positive hedonic value. According to Berlyne (1971) there are two separate

Figure 1

Relation of organism's arousal to stimulus arousal potential according to Berlyne. (Adapted from Hunt, 1973.)



mechanisms that must be distinguished to account for this relationship. One mechanism seeks to reduce arousal from unpleasant levels (called the arousal reduction or aversion mechanism); the other, called the arousal boost or reward mechanism, seeks moderate increments in arousal through encountering stimuli with moderate arousal potential.

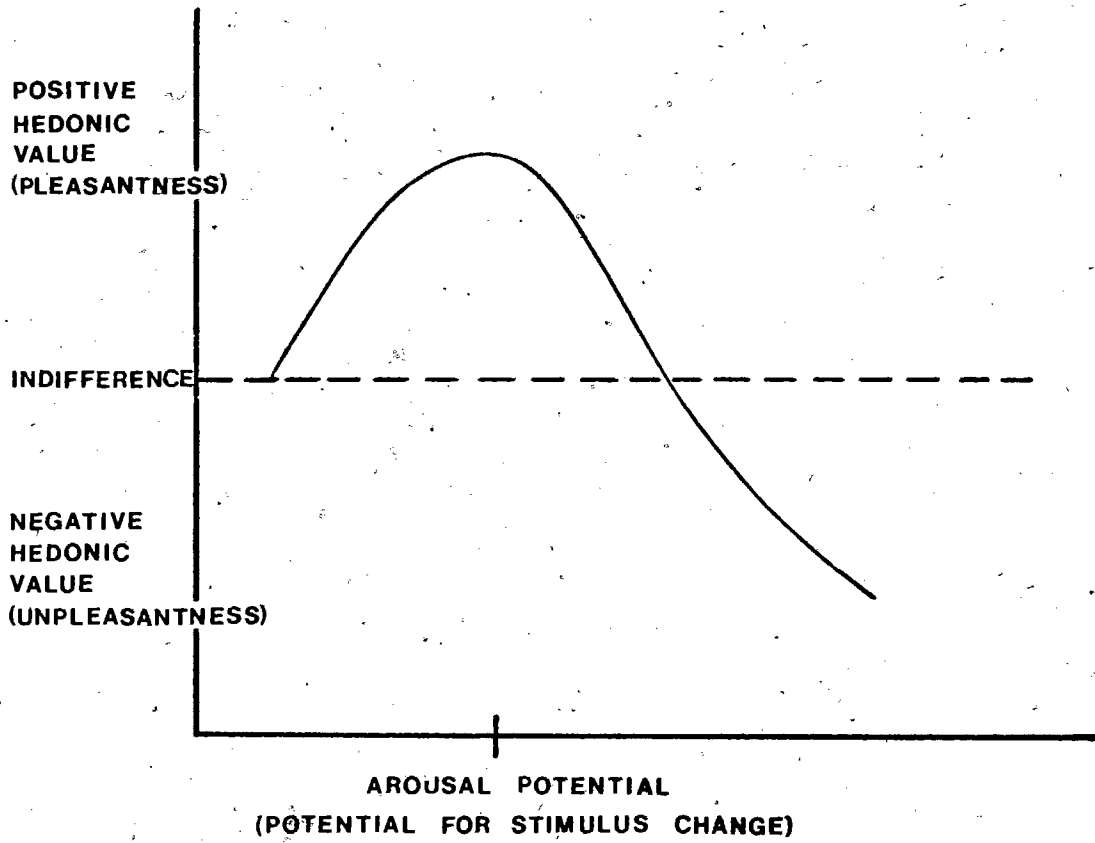
To clarify how his two mechanisms would operate, Berlyne (1973) reinterpreted Wundt's (1874) curve relating arousal potential to hedonic value (figure 2). When there is low arousal potential (no arousal change), the organism is indifferent. Stimulation is pleasant and hedonic value increases up to an optimum as arousal potential increases. After the optimum, hedonic value becomes less positive until once again there is a point of indifference. In this region between the optimum and indifference, both mechanisms will be operative and, as Berlyne suggests (1973) either stimulus onset or stimulus termination will be rewarding (i.e., either arousal increment or arousal decrement). Beyond the point of indifference, arousal potential is too great and the mechanism which places value on moderate arousal change will be essentially inoperative until arousal is reduced and arousal potential is at a more acceptable level.

Berlyne (1973) and Walker (1973) were the only theorists to explicitly postulate a two-mechanism approach to exploratory behavior (although such an approach was implicit in the work of Deamber and Earl, 1957; and Hunt, 1965). Berlyne was the only



Figure 2

Conceptualization of intrinsic motivation.  
(Berlyne, 1973.)



theorist, however, to discuss two corresponding kinds of exploration. Specific exploration refers to exploratory behaviors that are responses aimed at uncertainty reduction (thereby reducing arousal change). Diversive exploration, on the other hand, is aimed at providing stimulation (i.e., increasing arousal change).

In sum, Berlyne discussed how organisms behave to reduce arousal, but also to approach moderate levels of arousal change. In doing so he focused on the psychological level, but he also paid considerable attention to the physiological processes that underlie the behavior.

#### Summary

The evidence is quite clear. People and lower animals engage in a substantial amount of exploratory behavior, and theories need to be able to account for these behaviors, which are motivated both to reduce and induce stimulation, and which lead to learning in the absence of tissue-need related rewards.

Whereas drive-naming has been judged inadequate as a means of understanding exploration, both optimal-arousal and optimal-incongruity theories seem to easily handle these issues. Optimal arousal theories focus on the physiology of the nervous system and postulate that there exists in all exploring organisms an optimal arousal level below which they will seek to

increase stimulation and above which they will seek to reduce stimulation. Optimal-incongruity theory is primarily psychological but leads to the same behavioral predictions.

Whether one chooses to focus on the physiological theories or the psychological theories is really a matter of preference. Both are ultimately important and necessary and both have heuristic value. Also, theorists favoring one position give at least implicit recognition to the importance of the other (cf. Hebb, 1955, p.250 and Hunt, 1965, pp.207-212). Berlyne (1973) and Walker (1973), of course, are explicit in their references to both arousal and incongruity as contributing factors to exploratory behavior.

Many writers have chosen to classify all these theories under one modal label "optimal-level theory", preferring to concentrate on the heuristic benefits of their commonalities rather than on their ostensible differences (Arkes and Garske, 1977; Cohen and Gelber, 1975; Fowler, 1965; Nunnally and Lemond, 1973). I bow to the modal view. The rest of this thesis will deal with predictions common to all of the theories, i.e., predictions relating exploratory behavior to those stimulus properties determining its occurrence.

Optimal level theories all suggest a number of stimulus attributes having important and predictable influences on exploratory behavior. Included among these stimulus properties are those most succinctly categorized by Berlyne (1960) as

collative variables, with novelty and complexity receiving the most widespread theoretical attention. As well, most research on the area of exploratory behavior has been directed toward these variables and toward testing the predicted functional relationship between these variables and exploration.

The next section is a review of the concepts stimulus complexity and stimulus novelty. For each, a definition and a theoretically derived prediction concerning its relation to exploration will be outlined, followed by a discussion of the methods used for its investigation and the results found by previous research in the area of infant exploration. I will then argue that previous methods have been insufficient for tests relating complexity, novelty and exploratory behavior and propose a more suitable procedure.

#### Complexity -- Definition

The relation between stimulus complexity and exploratory behavior has been the focus of a vast amount of experimental effort as witnessed in this statement by Hutt (1970): "Certainly it (complexity) appears to be a concept that has challenged the ingenuity of many, to judge by the prodigious effort expended on its elucidation" (p.121). For many the major reason for investigating complexity and its relation to exploratory behavior has been its quantifiable nature (Cantor, 1963;

Attneave, 1954; Smock and Holt, 1962; Vitz, 1966). As a property of the distal environment, discernable in terms of its physical attributes, complexity is seen as more easily measured than other stimulus variables such as novelty, which depends in part on the history of the organism. Unfortunately, such optimism has been unfounded, since identifying those attributes that define the complexity value of a stimulus has proven elusive.

Definitions of stimulus complexity have included abstract definitions such as "stimulus heterogeneity" (Walker, 1964) and "dissimilarity between elements" (Berlyne, 1960), post hoc definitions determined by experimental results (Fantz, 1958), intuitive a priori definitions (intuitive in that the experimenter does not offer a rationale for ordering stimuli along a complexity dimension), for example, stripes vs. checkerboards vs. a bull's eye (Sackett, 1963), and specific a priori definitions such as number of squares in a checkerboard (Brennan, Ames and Moore, 1966; Caron and Caron, 1968) and number of toys in array (Rheingold and Eckerman, 1971; Ross, 1974; Hunter, Ross and Ames, in press), number of positions taken by flashing lights (Cohen, 1969), number of sides of 3-dimensional objects (McCall and Garratt, 1971), number of turns in a random shape (Hershenson, Munsinger, and Kessen, 1965; Munsinger and Weir, 1967), degree of redundancy in a pattern (Fantz and Pagan, 1975) and amount of contour (Karmel, 1969).

Most researchers now agree that explicit, a priori definitions are to be favored because they can be operationally defined, are more easily interpreted and more likely to lead to understandable accounts of the relation between complexity and exploration. Cohen and Gelber (1975), however, have pointed out that even in the face of such agreement there is still argument as to the relevant dimension governing stimulus complexity, i.e., contour density (Karmel, 1969) or size and number of elements (Fantz, Fagan and Miranda, 1975; Greenberg and Blue, 1975). Werner and Perlmutter (1979) have put forth a cogent argument favoring size and number and have also agreed with Fantz and Fagan (1975) that whereas size or both size and number are important for infants 6 months and younger, number of elements is the most important dimension of complexity for infants beyond 6 months of age.

The present study, which included 8 and 12-month-old infants, varied the number of elements in the stimuli by varying the number of toys in an array.

Complexity as a Determinant of Exploratory Behavior --  
Theoretical Prediction and Empirical Findings with Infants

Theoretical predictions relating stimulus complexity and exploratory behavior have been explicitly stated and unanimously agreed upon by all optimal level theorists (e.g., Berlyne, 1960;

Dember and Earl, 1957; Hunt, 1965; Walker, 1964). The predicted functional relationship is illustrated in figure 3. It suggests that exploration will be greatest when the stimulus to be explored is at an intermediate level of complexity, dropping off as stimuli become either "too" simple or "too" complex.

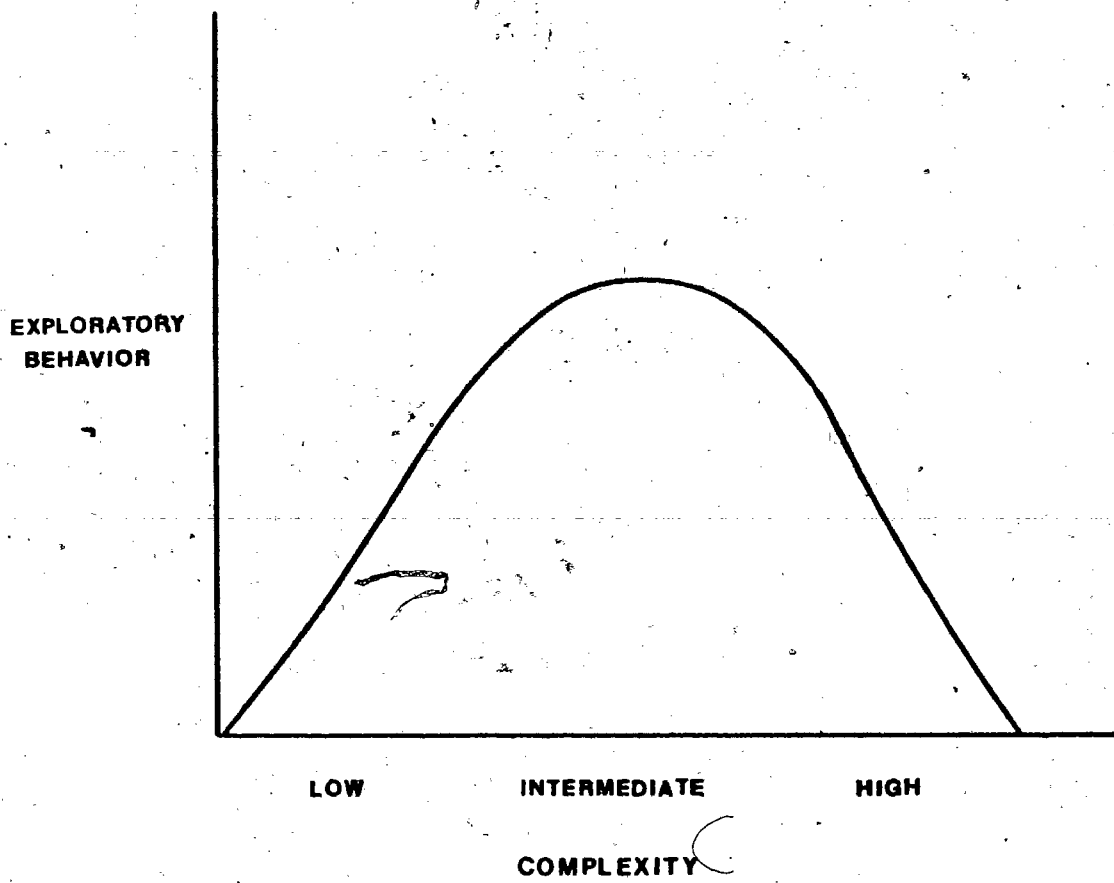
In order to investigate this relationship with infants, experimenters have most often used a procedure dating at least back to Marsden (1903). Stimuli are presented individually or two at a time and preferences among them are inferred from the rank ordering of amount of visual attention or focused manipulation spent with each.

With younger infants, visual attention is the response measure used. Lewis, Meyers and Kagan (1963) presented a single blinking light, a horizontal moving light, and a blinking light describing a square helix to six month old infants as described above. In terms of total fixation time the decreasing order of preference for the stimuli was the square helix, the line and the single light. From these results the authors concluded that "complexity is an important parameter in maintaining the infant's attention" (p.10). Moffett (1969) used stimuli composed of black lines variously arranged on white backgrounds. Infants 2 to 4 months old were found to prefer stimuli containing the largest number of parts into which the background was divided.

With older infants, focused manipulation is used as the response measure. Rheingold and Eckerman (1969) placed either

Figure 3

Theoretical relation between  
exploration and stimulus complexity.





one toy or six toys in a room separating 10-month-old infants from their mother. They found that toys delayed following, pointing out that the infants in the six-toy group spent more time manipulating the toys than did the infants in the one-toy group. Ross (1974) found that 12-month-olds allowed to approach and explore either four toys or one toy spent more time manipulating in the four-toy condition. If number of elements is taken as an index of complexity, four and six toys are more complex than one toy, indicating that 10 and 12-month-olds prefer complex stimuli over simple stimuli.

While these experiments and others offering similar results (Berlyne, 1958; Spears, 1962) found that complex stimuli promoted more exploratory behavior than simple stimuli, Hershenson, Munsinger and Kessen (1965) found that when stimuli containing 5, 10 and 20 angles were presented to newborns, the greatest attention was paid to the stimulus of intermediate complexity while the most complex stimulus was preferred second. In another study by Hershenson (1964) the stimuli used were three black and white checkerboards containing 2 x 2, 4 x 4 and 12 x 12 squares respectively. He found that newborns preferred the 2 x 2, or least complex stimulus. Further, the order of preference was in decreasing order of their complexity: the stimulus of intermediate complexity was the next most preferred while the most complex stimulus was least preferred.

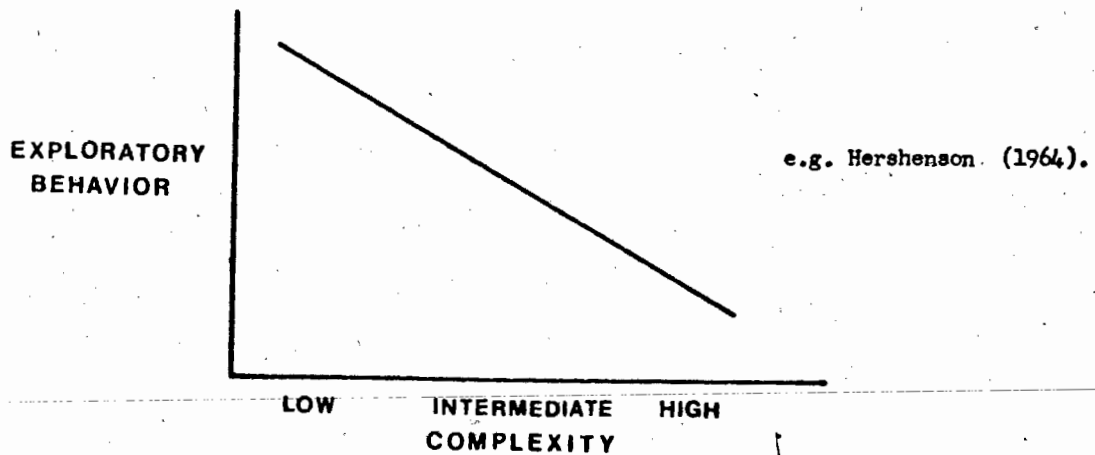
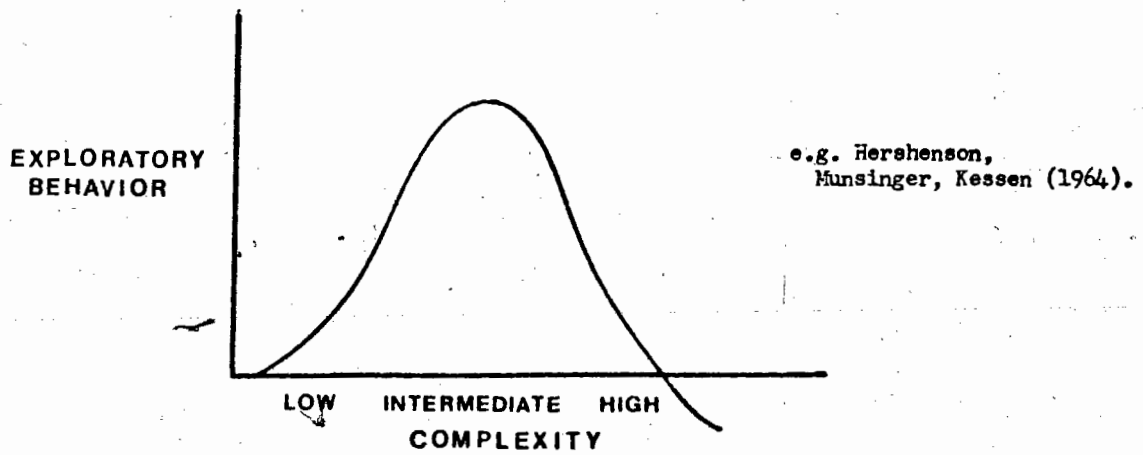
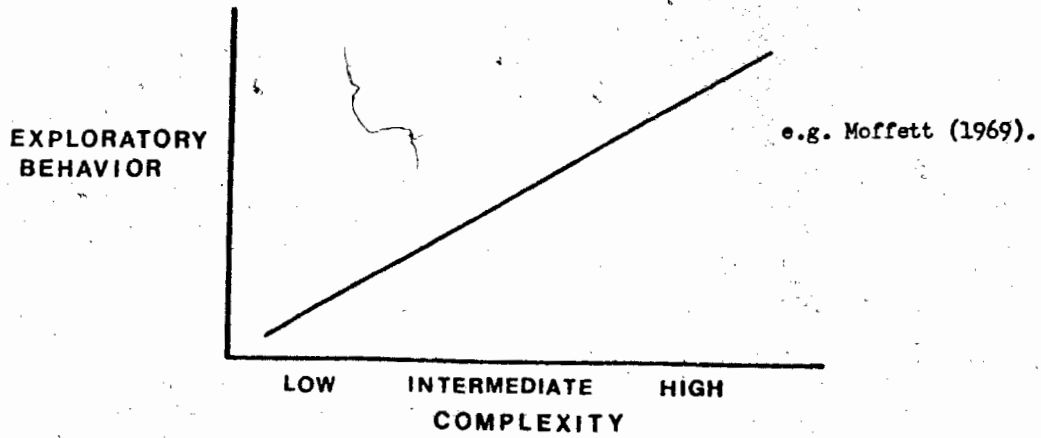
Taken together, then, these studies suggest that the relation between complexity and exploratory behavior can be described by any of three functions: monotonically increasing, inverted-U and monotonically decreasing (see figure 4).

The experiment which in effect resolved this dilemma was conducted by Brennan, Ames and Moore (1966). They noticed that those experiments that found a preference for either simple or intermediate stimuli included newborns or very young infants, whereas experiments showing a preference for complex stimuli involved older infants. The implication of these studies was that preference for complexity increases with age. A closer look at Dember and Earl's (1957) stimulus selection theory revealed that age changes in preference for complexity is a predicted possibility. As Dember (1961) pointed out: "What is too simple for an adult may be just right for a child" (p.360).

In order to test this prediction, Brennan et al. (1966) presented infants with three checkerboard stimuli comprised of 2 x 2 squares, 8 x 8 squares and 24 x 24 squares. According to a number of indices of complexity (e.g., number of elements, size of elements, amount of contour) the 2 x 2 checkerboard was least complex, the 8 x 8 intermediate and the 24 x 24 most complex. Their subjects were infants at 3 weeks, 8 weeks and 14 weeks of age. The 3-week-olds looked most at the 2 x 2 followed in order by the 8 x 8 and 24 x 24 checkerboards. The 8-week-olds spent more time looking at the 8 x 8 checkerboard than either the 2 x

Figure 4

Potential relations between stimulus complexity and exploratory behavior.



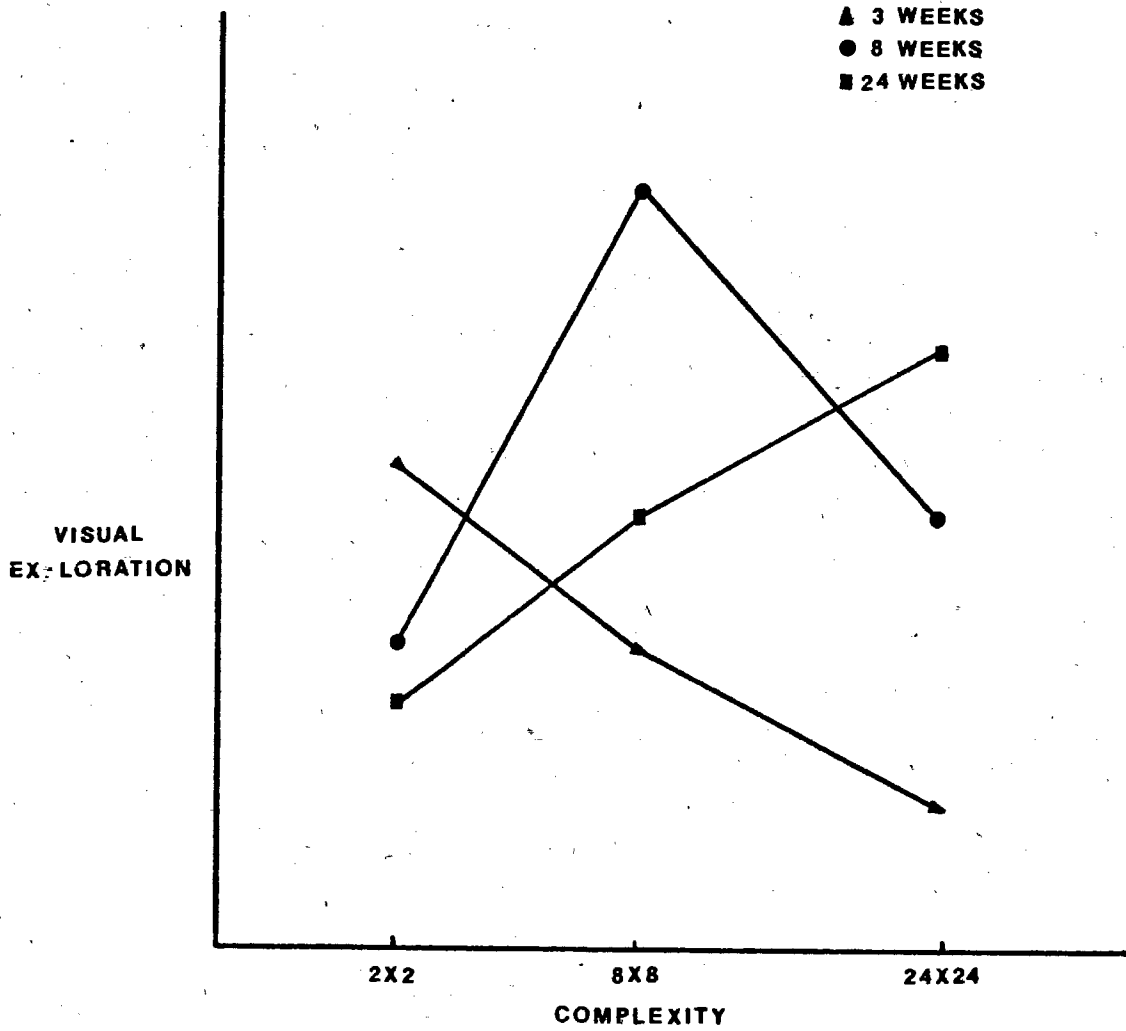
2 or the 24 x 24, which they looked at approximately the same amount. Finally, the 14-week-olds ordered their preference in decreasing order of complexity (see figure 5).

These results provided evidence that all three of the functions depicted in figure 4 could be found, depending on the age of the infant. Corroborative evidence of the Brennan et al. findings have since been forwarded by a number of researchers (Greenberg, 1971; Karmel, 1969, 1974; Jones-Molfese, 1975). Greenberg (1971) replicated the Brennan et al. findings using a longitudinal instead of a cross-sectional design. Defining complexity as amount of contour, Karmel (1969) found an inverted-U shaped function of preference and further found that the maximum evoked potential amplitude shifted towards stimuli with greater contour densities as age increased (Karmel, 1974).

The results of these studies demand a more sophisticated attitude toward the relation between stimulus complexity and exploratory behavior. Exploration does not appear to be a simple function of stimulus complexity but of stimulus complexity relative to the age of the infant. The message implicit to this attitude is that studies incorporating complexity as an independent variable should both define the dimension of complexity a priori (e.g., number of elements) and establish such age norms that the stimuli designated as simple and complex are indeed simple and complex for the age(s) of the subjects under investigation.

Figure 5

Age changes in preferred level of complexity.  
From Brennan, Ames and Moore, (1966).



The age-related definition used in the present research was based on Ross's (1974) finding that 12-month-old infants would explore, on average, only three or four available toys. Thus three or fewer toys would appear to be simple for this age group while four or more would be complex. In the study reported here, five toys were chosen as complex and three toys as simple for the 12-month-old group. The complexity level for the 8-month-olds was not chosen explicitly on the basis of prior research. However, it was chosen with "age-relatedness" in mind, i.e., the 8-month-olds received as their complex stimulus the same stimulus (three toys) that was simple for the 12-month-olds. Theoretically the implication of the Brennan et al. result is that there is one basic inverted-U shaped function relating complexity to exploratory behavior, although the complexity of the stimulus corresponding to the peak of the inverted-U varies directly with age. Presumably, if they had extended the complexity dimension to include simpler and more complex checkerboards, the 3-week-olds and the 14-week-olds would have shown inverted-U functions similar to the one shown by the 8-week olds. For the 3-week-olds, however, the stimulus most preferred would have been less complex than an 8 x 8 checkerboard, while a checkerboard more complex than an 8 x 8 would have been preferred by the 14-week-olds. Thus, the same stimulus (e.g., an 8 x 8 checkerboard) that would be perceived as simple for the 14-week-olds would be moderately complex for

8-week-olds and very complex for 3-week-olds. Analogously, I chose a 3-toy array, which is simple for the 12-month-olds, to be a complex stimulus for the 8-month-olds.

### Novelty -- Definition

Novelty has been widely described as a stimulus dimension having important and predictable influence on the occurrence of exploratory behavior. Precisely what novelty means and how it is best measured, however, has been a source of some concern (Berlyne, 1960; Hutt, 1970; McCall and McGhee, 1977). According to Berlyne, "when we ask what exactly it means to say that a stimulus pattern is novel and how novel it is, we face a whole succession of snares and dilemmas. To begin with there are several quite distinct senses in which something can be new (1960, pp.18-19). Berlyne categorized novelty into two discrete dimensions: a temporal dimension along which stimuli vary according to how much time has been spent interacting with them, and a spatial dimension on which stimuli are novel to the extent that they are combined in unfamiliar or unexpected ways.

A stimulus is said to be completely novel if it has never been encountered before. Short-term and long-term novelty refer to stimuli that have been encountered before but not within the last few minutes/hours (short-term) or day/months (long-term). On the spatial dimension, Berlyne distinguished absolute novelty from relative novelty. An absolutely novel stimulus is one which

has embedded within its configuration some attribute(s) that has never been perceived before. If the attributes of a stimulus are familiar, but are arranged in a way never before encountered, the stimulus is considered to be relatively novel.

To study the influence of novelty on exploration, these definitions must be translated into operational terms. Without complete knowledge of an individual's past, it is not possible to determine if a stimulus is either completely or absolutely novel. A more limited knowledge of the individual might enable you to specify the extent of long-term or relative novelty of a stimulus; however, even this information is generally absent. The easiest definition to work with has been short-term novelty since variations in it can be created within an experimental session. Studies typically involve pairs of stimuli with unknown and assumed equal relative novelty. This assumption is made valid by balancing the assigned roles of the stimuli between subjects. Subjects are provided with a specified amount of experience with one stimulus and it is then considered more familiar than the other stimulus. The degree to which a stimulus is novel (or familiar) can be measured by designating the amount of time spent interacting with it. A stimulus explored for some amount of time is less novel than that same stimulus before familiarization (intrastimulus novelty) and also less novel than a different stimulus that has not been as recently explored (interstimulus novelty). Thus, "the simplest operational



definition (of novelty)... is one which specifies novelty in terms of a time continuum along which an object which was once novel becomes familiar" (Saayman, Ames and Moffett, 1964, p.190).

### Novelty as a Determinant of Exploratory Behavior -- Theoretical Prediction

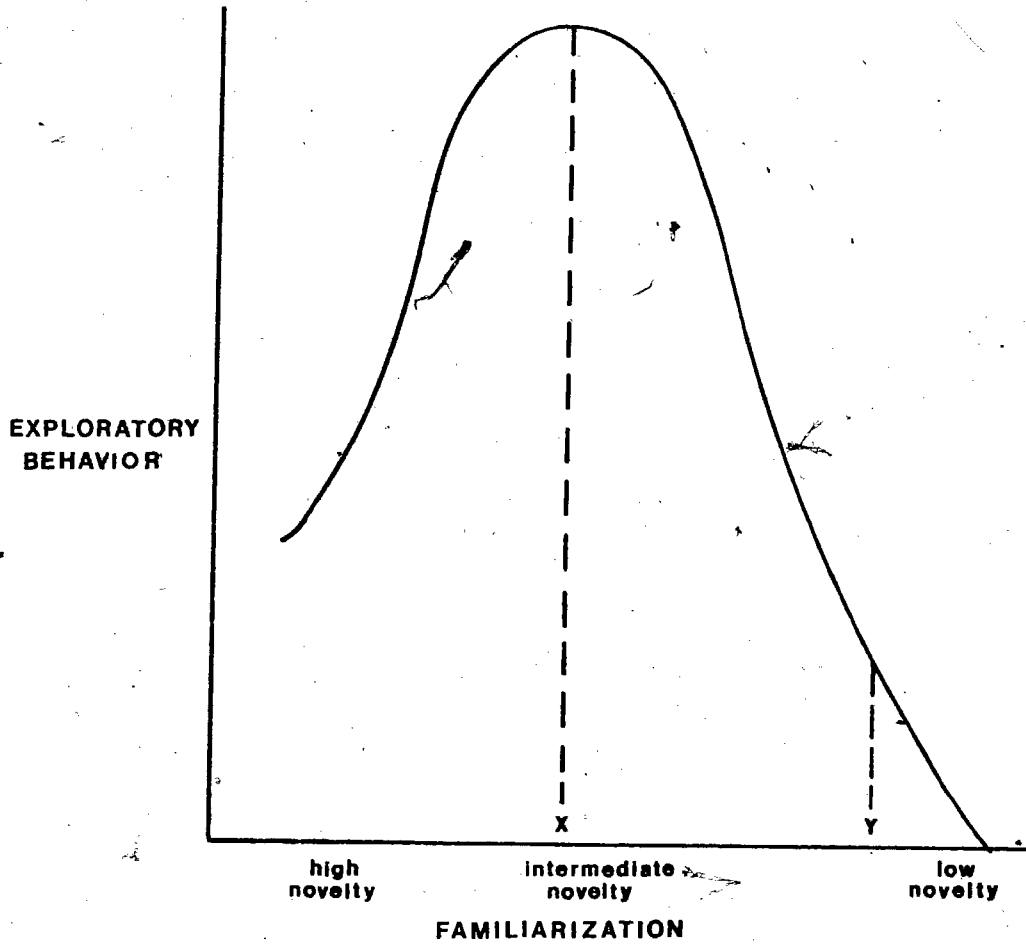
All of the theorists reviewed above have emphasized the role of novelty as a major determinant of exploratory behavior (Berlyne, 1960; Dember and Earl, 1957; Fiske and Maddi, 1961; Hunt, 1965; Walker, 1964). In general they predict an inverted-U shaped function that specifies both the course of exploration during familiarization of a simple stimulus (intrastimulus novelty) and how exploratory behavior will be affected when interstimulus novelty is varied.

The abscissa of figure 6 depicts a time continuum and the inverted-U curve describes how much exploration a single stimulus will elicit during the course of familiarization. Exploration is predicted first to increase as new information is assimilated, then decreases as information acquired becomes progressively redundant.

Predictions concerning interstimulus novelty also follow from figure 6. If familiarization proceeds to a point where the familiar stimulus will no longer sustain interest (e.g., at Y)

Figure 6<sup>a</sup>

Predicted course of exploration as a single stimulus becomes familiar (intrastimulus novelty).



- a. X and Y represent points where a novel stimuli is introduced and the times spent exploring the novel and familiar stimuli are compared. At point X the familiar stimulus is predicted to receive more exploration while at Y the novel stimulus should be preferred.

and a new stimulus is introduced, the new stimulus is predicted to receive more exploration. At point X, where interest in the familiar stimulus is increasing or still at a high level, the familiar stimulus is predicted to receive greater exploration. At point X, therefore, the novel stimulus should be explored less. (It should be noted that these predictions are subject to the restriction that the new and the familiar stimuli have equal novelty value prior to familiarization).

### Variations in the General Curve relating Novelty to Exploratory Behavior

#### Subject variables

Figure 6 can be interpreted as the general curve describing the relation between exploration and intrastimulus novelty for all organisms. However, the exact shape and the total amount of exploration a stimulus is likely to elicit may vary over individuals due to differences in previous experience (Berlyne, 1960; Dember and Earl, 1957; Hunt, 1970; Walker, 1973). For example, an older infant would presumably have more experience with and greater knowledge of the stimulus. Thus, a given stimulus might be expected to initially be less novel and the older infant would be expected to take less time to explore the stimulus than a younger infant (Dember and Earl, 1957).

Other things being equal (e.g., the complexity of the stimulus) the older infant should begin exploring at a later point on the curve than a younger infant (see figure 7).

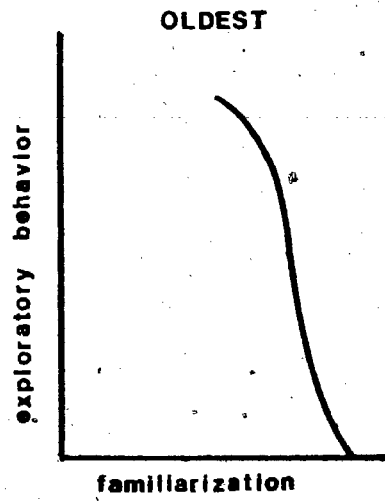
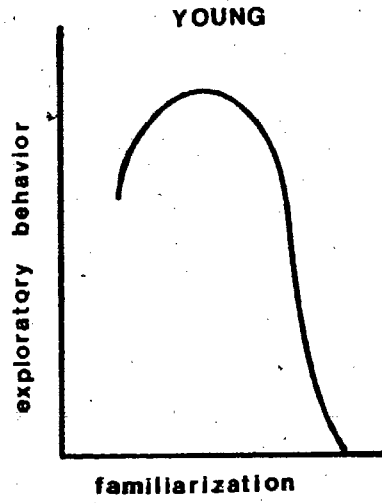
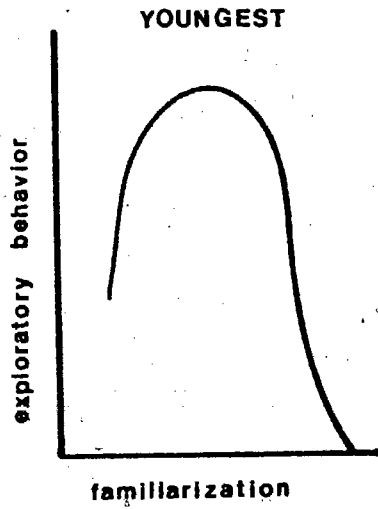
Individual differences within the same age range might also be expected to lead to differences in the shape of the curve as in figure 7. Differences in genetic disposition and experience would result in individuals starting at different points on the curve and reaching the endpoint at different rates.

Stimulus variables: The interaction between novelty and complexity

Walker (1964) maintained that stimulus complexity and stimulus novelty interact as determinants of exploratory behavior, as did Dember and Earl (1957) and Berlyne (1960, 1970). Berlyne (1970) proposed that changes in exploratory behavior depend on the interaction of two antagonistic processes: tedium and positive-habituation. A stimulus gradually succumbs to a tedium factor as it is repeated or prolonged. Positive-habituation reflects an increased liking for a stimulus as information is absorbed from it and the stimulus becomes assimilated or organized. Hence, the inverted-U function for exploration. Berlyne claimed further that these two factors are weighted differently depending on the complexity of the stimulus. "One would expect the tedium factor to be relatively stronger when the stimuli are simple and low in information

Figure 7

Possible variations in exploration according to age, when stimulus attributes, e.g. complexity are assumed to be constant.



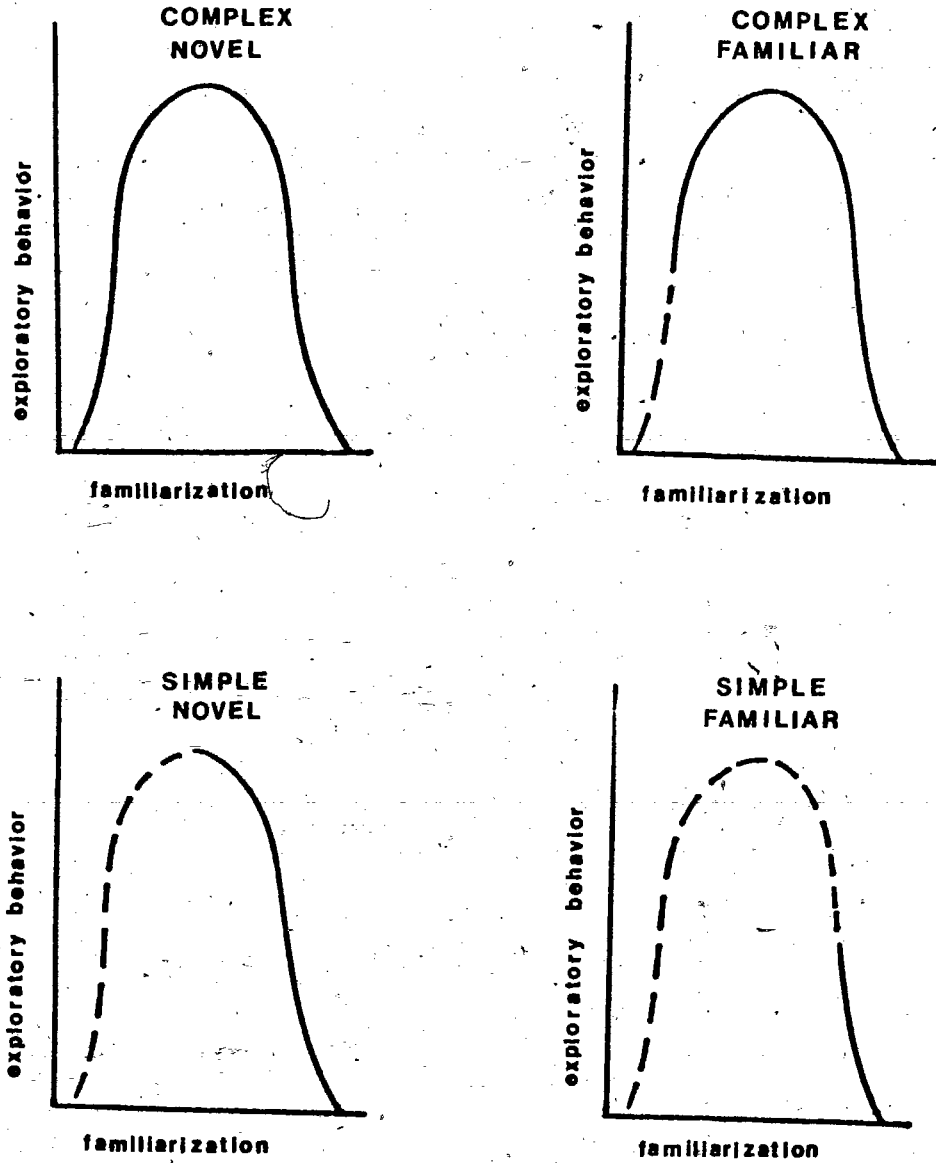
content, whereas there will be more scope for the information processing presumed to underly the positive-habituation factor when stimuli are complex" (1970, p.121). The manner in which these mechanisms work are summarized in figure 8. Simple stimuli, whether novel or familiar, should show a monotonically decreasing function of exploration with familiarization over time. Both complex-novel and complex-familiar stimuli, however, should produce an inverted-U shaped function over the course of familiarization time.

Notice that Berlyne predicted minimal or no initial exploration of complex-novel stimuli. This section of the curve might be thought of as an exception to the more general starting point depicted in figure 6, and perhaps is characteristic only of completely or absolutely novel stimuli. Complex-familiar, simple-novel and simple-familiar stimuli probably represent those most often used in research on exploration.

Predictions concerning interstimulus novelty would also depend on the complexity of the stimulus being explored. Referring back to figure 8 it is apparent that preferences for familiar stimuli are tenable only when the stimulus being familiarized is complex. If simple, the familiarized stimulus should not be preferred following even a short familiarization period. Instead, either no preference (following a short amount of familiarization) or a preference for the novel stimulus (following a longer amount of familiarization) should occur.

Figure 8

Possible variations in exploration according to complexity when previous experience is assumed to be constant.



In sum, optimal level theories predict that either a novel or a familiar stimulus will be preferred depending on (a) how long the familiar stimulus has been previously exposed, and on (b) the complexity of the stimulus, where complexity is defined relative to the age of the explorer.

#### Methodology for investigating novelty -- Habituation

The method most often employed to investigate the relation between exploratory behavior and both intra- and interstimulus novelty has been the habituation paradigm. Typically, a stimulus is presented for some number of discrete trials or for some amount of continuous time. Following these "habituation trials" the familiar stimulus and a novel stimulus are presented either simultaneously or successively and the amount of exploration elicited by each is compared. Analyses of the course of exploration over the habituation trial(s) can provide information about the function relating exploration and intrastimulus novelty. The relation between interstimulus novelty and exploration can be studied by looking at the relative response to novel and familiar stimuli during the comparison trial(s). By comparing different ages, sexes, and stimuli, developmental and individual differences in this relation can be investigated.



Intrastimulus novelty -- the course of exploration during habituation

Shape of the curve

Many studies of infant habituation have reported a monotonically decreasing curve of habituation (Caron and Caron, 1969; Cohen, 1969; Pagan, 1977; Hutt, 1970; Kagan and Lewis, 1965; Lewis, Padel, Bartels and Campbell, 1966; Ross, 1974). These studies all presented infants with a single stimulus for a set number of fixed length trials or for a fixed amount of continuous time. Habituation curves were constructed by averaging subjects' response times for each trial and plotting mean scores forward from trial one to the last trial (see figure 9).

Cohen and Gelber (1975) have argued that the negatively exponential decline described by the typical habituation curve is an artifact produced by individual subjects habituating at different rates. They suggested that a more representative curve is produced when subjects are run to an individual criterion of habituation and the curve is plotted backwards from the point at which criterion is reached. As shown in figure 10, rather than gradually declining, curves plotted in this way suggest that exploration first increases from its initial value, continues at a high rate, then peaks and finally declines rapidly to

Figure 9

Typical forward habituation curve.  
(From L. B. Cohen and E. R. Gelber, 1975.)

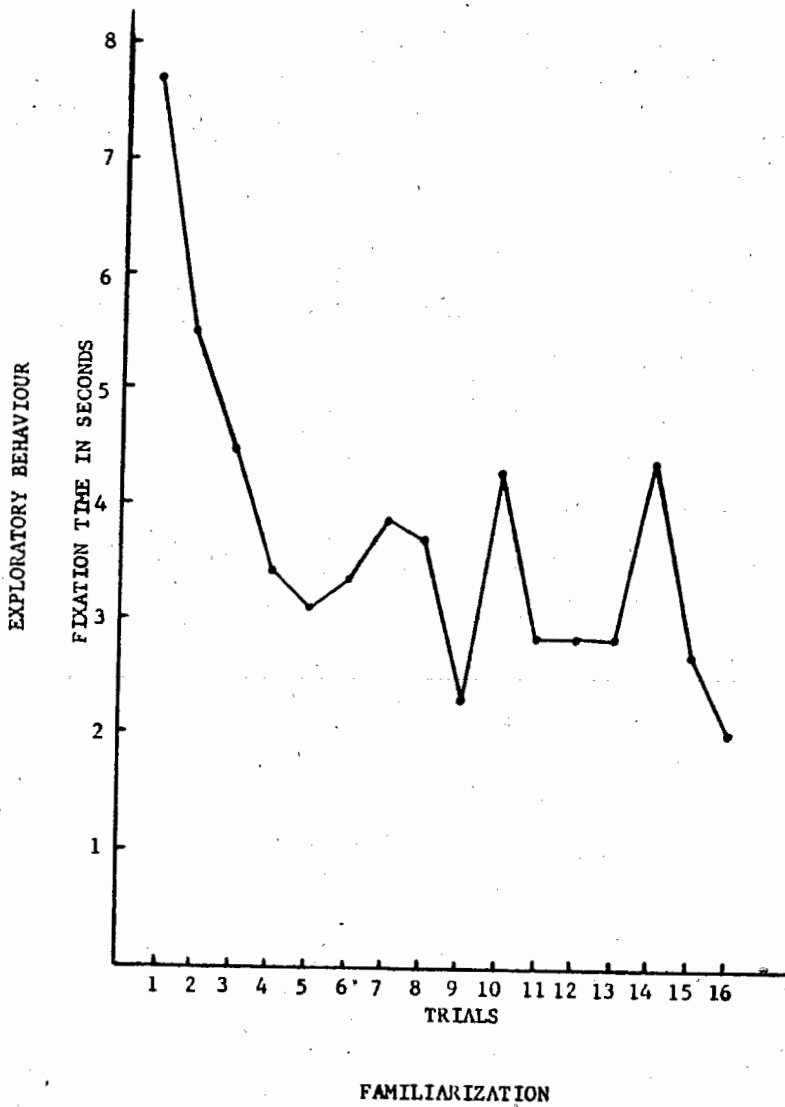
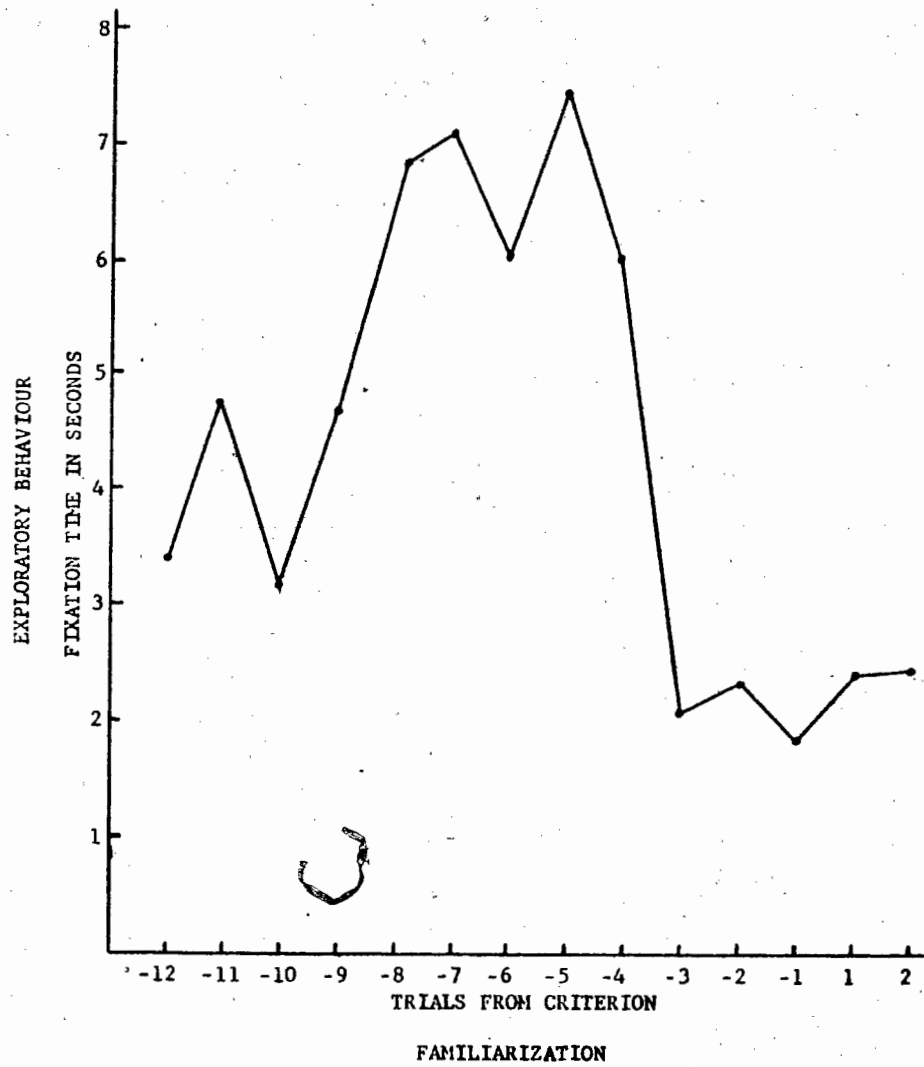


Figure 10

Backward habituation curve.  
(From L. B. Cohen and E.R. Gelber, 1975.)



criterion. The curve is not entirely symmetrical but is roughly similar to an inverted-U.

More recently, Cohen and Menten (1979) have criticized the backward curve as also being artifactual. In particular the peak and the rapid decline occurring just prior to criterion are seen as resulting from the artificially restricted trial immediately prior to the criterion trial(s) (artificially restricted because the first pre-criterion trial must, by definition, be higher than the criterion trial(s) in order not to be included in the criterion). Interestingly, Hayes (1953), the first person to propose using backward curves for the study of learning, was aware of this artifact. He pointed out, however, that if criterion trials and the first pre-criterion trials are discarded, and only points contributed to by a large majority of subjects are interpreted, backward curves are sensitive to the course of learning. The same might be true for backward habituation curves: although the rapid decrease from the first pre-criterion trial to criterion is undoubtedly due, at least in part, to artifact, perhaps the earlier increase and any rapid drops from trials near to but not immediately preceding criterion (which are both evident in figure 10) are real.

More evidence challenging the verity of the monotonically decreasing habituation curve has been reported by McCall (1979). He used a sophisticated combination of statistical techniques to first extract generalized habituation patterns, then to locate

groups of subjects who were simultaneously homogeneous within and heterogeneous between with respect to pattern. The results showed habituation curves for approximately 50 percent of 5-month-olds and 90 percent of 10-month-olds that generally supported the attributes suggested by the more biased backward habituation curves. Thus, there is evidence to suggest that habituation does not unconditionally display a monotonically decreasing pattern. Rather, for a significant number of individuals the curve may best be described by a curve that approximates an inverted-U. Further, Cohen and Gelber agreed that such curves are "consistent with optimal level of stimulation theories which predict an inverted-U relationship between attractiveness and familiarity" (1975, p.363).

As they do for stimulus complexity and exploration, optimal level theories predict a single basic inverted-U shaped function relating intrastimulus novelty and exploration. The incidence of both monotonically decreasing and inverted-U curves would belie this prediction unless, as was suggested by Berlyne (1960, 1970), their occurrence was found to vary systematically with individual differences in prior experience, with stimulus variables such as complexity, or with both.

## Variations in the course of habituation

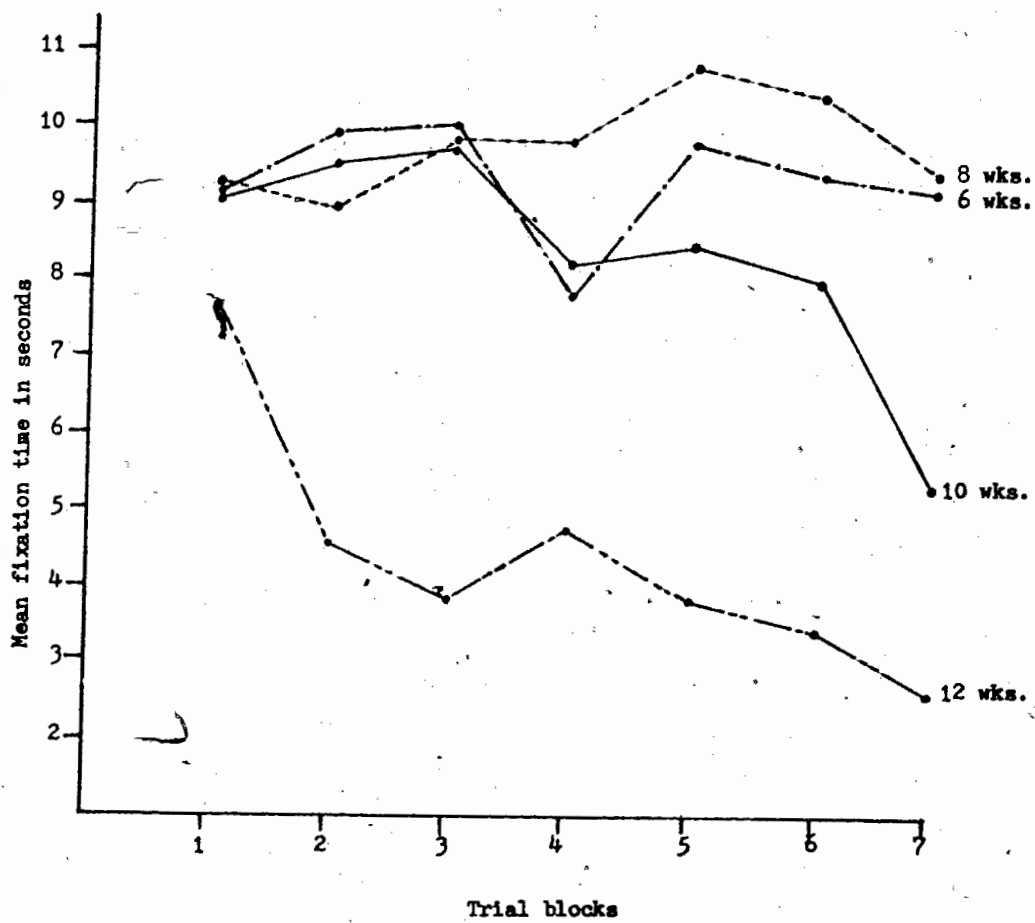
### Subject Variables

Wetherford and Cohen (1973) presented 6-, 8-, 10-, and 12-week-old infants with 2-dimensional geometric forms for 14 15-second trials. The habituation curves for each age group are presented in figure 11. Whereas the 10- and 12-week-olds decreased their visual exploration over trials, the 6- and 8-week-olds either maintained a high level or increased their exploration. Wetherford and Cohen originally interpreted these data as support for an age-based difference in habituation and agreed with Jeffrey and Cohen (1971) that the basic capacity to habituate does not develop until after 2 months of age. Another potential explanation is that the shape of the curve relating exploration to intrastimulus novelty is determined by age. For example, infants 2 months and younger may be best described by that section of figure 6 which shows increasing exploration over time, while the decreasing half would best characterize infants older than 2 months.

Although these explanations are parsimonious for the Wetherford and Cohen data, recent findings have left them somewhat exiguous. Using criterion of habituation procedures, which allowed infants consistently more familiarization time than constant-time procedures, Black (1976), Friedman (1975) and

Figure 11

Age differences in habituation curves  
(From Wetherford and Cohen, 1973.)



Milewski and Sigueland (1975) have found that infants younger than 2 months, even newborns, eventually decrease their exploration. According to these studies, rather than an age-determined difference in curve shape or in the basic capacity to habituate younger infants simply require more time in order to show a response decrement.

This interpretation is congruent with evidence from studies of infants beyond 3 months of age, showing that older infants generally habituate faster than do younger infants (Cohen, 1969; Pagan, 1974; Lewis, 1971; McCall, Hoarty, Hamilton and Vincent, 1973; McGurk, 1972). In fact, Cohen later altered his interpretation of the Wetherford and Cohen results and suggested that "perhaps if the earlier study had provided additional trials, younger as well as older infants would have habituated" (1976, p.214). Perhaps too, had fewer trials been allowed, older as well as younger infants would have shown high or increasing rates of exploration. Inspection of figure 11 indicates that this would have been true at least for 10-week-olds.

Taken together, these are provocative findings. For example, they support optimal level theories by suggesting that amount of experience, a correlate of age, rather than age per se may account for differences in the shape of the curve relating exploration and intrastimulus novelty. In other words, habituation is age-related not age-determined.



This notion is further strengthened by evidence of individual differences in curve shape and rate of habituation within as well as between ages. McCall and his colleagues (McCall, 1971, 1972; McCall and Nelson, 1969; Nelson and McCall, 1970) have reported that infants within several age groups (e.g., 3, 4, and 5 months) could be characterized as either rapid or slow habituators. The visual exploration of "rapid habituators" displayed linearly decreasing response decrements while "slow habituators" continued to explore at a high rate or showed a response increment. (It should be noticed that the term "habituation" seems to be a misnomer for this group, since its members did not show a response decrement during the constant time period allowed.) Hunter (1978) reanalyzed data from Ross's (1974) study and found similar results for 12-month-olds: i.e., following 5 minutes of continuous familiarization 59 percent of the infants had decreased their exploration, while 41 percent continued to explore at a consistently high or increasing rate. As in Wetherford and Cohen's (1973) study, these results were based on constant time familiarization procedures and on the curves being plotted forward in time. Work by Deloache (1973), McCall (1979) and McCall, Hogarty, Hamilton and Vincent (1974) using criterion measures of habituation found that rapid and slow habituators alike would decrease their exploration but that slow habituators required more familiarization time. When Cohen and Gelber (1975) constructed backward-habituation curves using

Deloache's (1973) data, slow habituators produced a protracted inverted-U curve, while an almost immediate peak followed by a rapid decline to criterion characterized rapid habituation.

Thus, slow habituators behaved as if the familiarized stimulus was initially more novel for them than for rapid habituators. They showed an increase in exploration when familiarization time was relatively short and required relatively more familiarization time before a response decrement could be produced. Since rapid and slow habituators did not differ in age, the difference between them in curve shape and in time needed to habituate could not be due to age. The most parsimonious interpretation for the present is that for whatever reason, slow and rapid habituators enter into an experimental session having had different histories of interaction with their environment and therefore differ in previous experience relevant to the experimental stimulus.

#### Stimulus variables

Not only does habituation vary according to differences in previous experience, it is also sensitive to differences in stimulus complexity. Caron and Caron (1968, 1969) reported that the habituation rate for 3 1/2-month-olds was fastest to a 2 x 2 checkerboard and progressively slower to 12 x 12 and 24 x 24 checkerboards respectively. Similar findings of faster habituation to simpler stimuli were obtained by Cohen, Deloache

and Rissman (1975) with 17-week-olds and by Ross (1974) with 12-month-olds.

Cohen and Gelber (1975) have suggested that stimulus complexity accounts for differences in the shape of the habituation curve. They found that 4-month-olds familiarized to an individual criterion stimulus (24 x 24 checkerboard) produced an inverted-U shaped curve, while a monotonically decreasing curve was found when the stimuli were simpler (2 x 2 or 8 x 8 checkerboards). Thus, the rate of habituation and the shape of the curve appear to vary with the complexity of the stimulus being familiarized.

These findings can also be used to further account for the age differences in habituation mentioned above. That is, since habituation is dependent upon stimulus complexity and effective complexity has been found to vary with age, habituation should be expected also to vary with age. Consider again Wetherford and Cohen's (1973) reported age differences in habituation. Not only was it likely that infants at different ages differed in previous experiences, but since all infants were familiarized with the same stimuli, the younger infants in effect may have been familiarized with (what was for them) a more complex stimuli. Conversely, the typical results relating complexity to habituation when found for a particular age group and with a particular set of stimuli may not generalize to other age groups. Caron and Caron (1968) found response decrement to be

inversely related to stimulus complexity for 3 1/2-month-olds. However, using virtually identical checkerboard stimuli, Brown (1974) found habituation in 2-month-olds to be fastest for the least and most complex stimuli and slowest for a stimulus of intermediate complexity. In one of the few studies to investigate directly the relation between habituation and complexity at different ages, Ames (1966) found greater response decrement to the simpler of two checkerboard stimuli (2 x 2 versus 8 x 8) for 5 1/2-week-olds, but no difference for 11-week-olds. An interpretation in line with the studies presented thus far is that these stimuli were probably "simple" (2 x 2) and "complex" (8 x 8) only for the 5 1/2-week-olds and therefore would be expected to lead to differences in habituation rate. For the 11-week-olds habituation rate may have been the same across stimuli because for them both stimuli were "simple" (cf. Brennan, Ames and Moore, 1966). Thus Ames' study makes the point that habituation is not a simple function of complexity or of age taken separately but rather of age-related complexity.

In sum, the studies presented to this point can be interpreted as support for optimal level theories of exploration. There is some evidence for a general inverted-U shaped curve relating intrastimulus novelty and exploration which varies systematically with previous experience and with age-related complexity.

Beyond theoretical support these studies also suggest that in order to find the same pattern of exploration over time for all individuals, procedures must be used that allow for predictable individual differences. A first step in this direction is to allow infants to be familiarized to an individual criterion of habituation, thereby helping to ensure that all infants reach the same relative response decrement regardless of the time each separately requires. Even when run to a criterion, however, the overall pattern of the curve may still differ among individuals (e.g., between rapid and slow habituators and between different age groups). In order to accomplish similarity in pattern, a further step is necessary: i.e., consideration of the particular stimulus to be familiarized. Since habituation is determined by complexity level, one should take measures to ensure that the stimulus to be familiarized is at a level of complexity most likely to produce a particular curve. For example, in order to find only decreasing curves, the stimulus should be one that is simple even for slow habituators. Similarly, by selecting a stimulus that is complex even for rapid habituators the likelihood of inverted-U curves for all infants would be increased. Further, since complexity is age related, the particular "simple" or "complex" stimuli chosen should be appropriate for slow and rapid habituators at the particular age being studied. In the present study stimuli were chosen to be simple or complex for 8-

and 12-month-old infants (see page 30) and infants were assumed to have habituated equally when their exploration had decreased by the same proportional amount, i.e., to one-half their initial level of exploration.

Interstimulus novelty: Preference for familiar and novel stimuli

The shape of the habituation curve has implications for the relation between interstimulus novelty and exploratory behavior. Recall that according to optimal level theories preference for novel or familiar stimuli depends both on when during familiarization preference tests are made, and on the shape of the curve relating interstimulus novelty to exploration. When comparisons are made after exploration has declined to a low level, preference for a novel stimulus is predicted regardless of the shape of the curve. However, when comparisons are made prior to completing habituation and when exploration of the familiar stimulus is still at a high level, preference for the familiar stimulus is expected if the curve is inverted U-shaped. If the curve is monotonically decreasing either no preference or an attenuated novelty preference is expected. Variables affecting intrastimulus novelty, therefore, are also pertinent for interstimulus novelty.

Most studies reporting preference for novel or familiar stimuli have not included comparison trials at more than one

point during familiarization. Instead, they have used the habituation paradigm in its traditional form where preference testing occurs only at the end of the familiarization period, purportedly when habituation has been completed. The reason for the use of this procedure has been that most studies have not been directed toward testing theoretically derived predictions concerning variables affecting exploratory behavior. Rather, they have used the habituation paradigm either as a method for studying habituation per se as a mechanism of behavioral change (e.g., Clifton and Nelson, 1976; Jeffrey, 1976; Sameroff, 1972), as a method for studying infants' ability to discriminate among stimuli (e.g., Cornell, 1975; Fagan, 1970; McGurk, 1972; Saayman, Ames and Moffett, 1964) or as a method for studying infant recognition memory (e.g., Caron and Caron, 1969; Fagan, 1972, 1973; Pancratz and Cohen, 1970; Gottfried, Rose and Bridger, 1978; Rose, 1980). For most of these authors, the main concern is that novelty preferences be produced. For example, to those interested in habituation per se, novelty preference is required as the sine qua non of the presence of habituation. In its absence fatigue or general change in state can be attributed as the causal factor of response decline. Preference for a novel stimulus has also been used as the measure of discrimination ability or of recognition memory as evidenced by the practise of testing for novelty preference using one-tailed statistics (e.g., Cornell, 1979; Gottfried, Rose and Bridger, 1978). Cohen

and Gelber (1975) have pointed out, however, that evidence for the presence of discrimination or recognition could be provided by a familiarity preference just as well as by a novelty preference. As long as systematic differential responding to two stimuli takes place and the stimuli are equivalent (or counterbalanced) prior to familiarization, both recognition and discrimination can be concluded.

Investigators more centrally interested in exploration have relied heavily on results from habituation, discrimination and memory studies in their discussions of the relation between interstimulus novelty and exploratory behavior (Hunt, 1970; Hutt, 1970; Nunnally and Lemond, 1973; Weisler and McCall, 1976). Moreover, they have most often used in their own research (e.g., Hutt, 1967; McCall, 1974; Greenberg, Uzqiris and Hunt, 1970; Nunnally and Lemond, 1973; Ross, 1974) the same procedures used in those studies. Since the direction of preference for novel or familiar stimuli is important for theories of exploratory behavior and since a complete test of direction requires comparison trials both prior to and after habituation has been completed, this ostensible sharing of methodology may have led investigators away from testing major theoretical predictions and toward specious conclusions concerning preference behavior.



### Common empirical findings from research on interstimulus novelty

There is consistent evidence that infants beyond 2 months of age prefer to explore novel stimuli (Cohen, 1969, 1976; Fagan, 1973, 1977; Gottfried, Rose and Bridger, 1979; McCall, 1974; Ross, 1974; Saayman, Ames and Moffett, 1964; Soroka, Corter and Abramovitch, 1979). The stimuli used in these studies varied from checkboards to pictures and from 3-dimensional abstract objects to toys. The measurement of exploration included visual fixation, manipulation and focused manipulation and the experimental sessions took place in both lighted conditions and in the dark. Thus the generality of the findings seem confirmed. For infants younger than 2 months the picture is more complicated. Some studies have reported familiarity preferences (Greenberg, Uzqiris and Hunt, 1970; Wetherford and Cohen, 1973; Weizmann, Cohen and Pratt, 1971) while others have found novelty preferences (Friedman, 1972, 1975; Milewski and Sigueland, 1975) and still others no preferences at all (Fantz, 1964).

In order to interpret these data, Nunnally and Leonard (1973) focused on the prevalence of novelty preference and suggested a tropism to approach and explore novel stimuli. Fantz (1964) posited a monotonic relationship between age and preference for novelty whereby an initial age of no preference (prior to 2 months) gradually accrues into an increasingly

strong preference for novel stimuli as infants get older. In contrast to these positions, Hunt (1965, 1970) proposed a two-stage developmental sequence of an initial preference for familiarity in infants younger than 2 months followed thereafter by a preference for novelty. Increased cognitive capacity due to neurological maturation has been suggested as the factor governing this age difference (Kagan, 1971).

Obviously, none of these explanations can entirely account for the available data, especially for the lack of consistent results in infants less than 2 months old. An alternative explanation in line with optimal level theories would suggest that although there is a progression from preference for familiarity to preference for novelty, it is present at all ages and depends on whether or not habituation has been accomplished, which in turn is dependent on the length of familiarization and on the complexity of the stimuli. Indeed, Hunt (1970) did not deny this possibility. He pointed out that the data do not clarify whether the familiarity to novelty progression is due to maturation, or whether it is representative of an organism's interaction with stimuli in general. Since procedures systematically testing for preferences both prior to and after habituation with both simple and complex stimuli have not been used, the tenability of this interpretation has not received adequate empirical testing. Even in the absence of a clearcut test, however, past findings of age differences in preference

for novel or familiar stimuli should be explainable in terms of amount of familiarization and degree of response decrement, if those factors are to represent a viable alternative. Further, since preferences for both familiar and novel stimuli have been noted in infants less than two months, the burden of proof for new research directed towards testing this hypothesis lies in finding familiarity preferences among infants beyond 2 months of age.

Greenberg, Uzqiris and Hunt (1970) and Weizmann, Cohen and Pratt (1971) familiarized infants for daily half-hour periods beginning at 4 weeks of age and continuing until the infants were 10 weeks old. At 6 and 8 weeks infants preferred familiar stimuli whereas 2 more weeks of familiarization switched their preference to novel stimuli. However, preference not only changed with increased age, it also changed with increased familiarization time. Infants who preferred familiar stimuli were simultaneously the youngest and the least familiarized, while the oldest most familiarized infants preferred novel stimuli. Familiarization time, therefore, could just as well have been the effective variable accounting for the familiarity-to-novelty progression. Unfortunately, data concerning the pattern of exploration over time was not reported in these studies so that determining the degree of response decrement prior to each preference test is not possible.

In a short-term study, Wetherford and Cohen (1973) familiarized infants for 3 1/2 minutes and reported an age-related progression where 6-week-olds showed no consistent preference for either novelty or familiarity, 8-week-olds preferred the familiar stimulus and 10- and 12-week-olds preferred the novel stimulus. Although infants did not vary in amount of familiarization time, they did vary in degree of response decrement which in turn covaried with age (see figure 9). Those infants who decreased their exploration (10- and 12-week-olds) subsequently preferred novel stimuli, while a subsequent preference for the familiar stimulus was shown by those infants who had increased their exploration over time (8-week-olds). The 6-week-olds who showed no change in exploration over time may have required even more familiarization in order to increase their exploration enough to show a familiarity preference. A suggestion that age *per se* was not the predominant factor comes from Friedman (1972), who found that newborns would spend more time exploring a novel stimulus following a decrement in their response. Compared to the 3 1/2 minutes of familiarization in Wetherford and Cohen's study newborns were tested for preference, on average, after 20 minutes of familiarization. Thus *post hoc* inspection of studies reporting age differences in preference behavior indicates that amount of familiarization and degree of response decrement have considerable (albeit confounded) power as predictors of

direction of preference.

Corroboration for this reasoning is provided by the work on slow and rapid habituators. Recall that although the former group has been termed "slow habituators", their most important characteristic may be their continued high rate of exploration over time. Consequently, they should be expected to spend less time exploring novel stimuli than rapid habituators who decrease their exploration with familiarization. Several studies have demonstrated this to be true (McCall, 1971, 1972; McCall and Nelson, 1969; Nelson and McCall, 1970). That slow habituators actually preferred the familiar stimulus (i.e., spent significantly more than 50 percent of their time with it) has not been reported. However they certainly represent evidence that degree of response decrement is related to time spent with novel and familiar stimuli and importantly, this evidence comes from infants who are beyond 2 months of age.

To this point, the evidence presented has been based on post hoc analyses and as such cannot be used to conclude that familiarization time and degree of response decrement are the causal factors determining preference behavior. Happily, it is buoyed by more recent research that has experimentally manipulated amount of familiarization time.

Fagan (1974) familiarized infants 5-6 months old for varying amounts of time with stimuli varying in complexity. (For example, geometric patterns were shown for either 10 or 20

seconds while either 20 or 30 seconds of familiarization was used with photographs of faces). In a subsequent 10 second test trial he found a stronger novelty preference for simple relative to complex stimuli and for longer periods of familiarization relative to shorter periods. What amounted to an interaction between complexity and familiarization was also evident. Stronger novelty preferences for simple stimuli were found for equal, short familiarization times but were eliminated with longer familiarization times. Although novelty preferences were attenuated as familiarization decreased and complexity increased, significant preference for familiar stimuli did not occur. At most no preferences for either the novel or the familiar stimuli were found. Since habituation curves were not reported, it is not possible to ascertain the level of exploration prior to the test trials. However, for infants at 5-6 months, all the stimuli were likely to have been relatively simple and the habituation curves monotonically decreasing. Comparable findings were reported by Cornell (1979, experiment I) who also studied 5-6 month olds. Stimuli nearly identical to those used by Fagan were presented until either 5 or 10 seconds of visual exploration had accumulated to simple and more complex stimuli respectively or until 15 or 20 seconds had accumulated. Cornell found no preference for either the novel or the familiar stimuli following 5 and 10 seconds but he found significant novelty preferences after familiarization was increased to 10

and 20 seconds.

Caron, Caron, Minichiello, Weiss and Friedman (1977) compared the novelty preferences of 14- and 20-week-olds following different amounts of familiarization to a variety of stimuli. Overall, magnitude of novelty preference was found to be a positive function of familiarization time and degree of response decrement and a negative function of stimulus complexity. Further, the younger infants required more familiarization time in order to show novelty preferences comparable to older infants. As in Fagan's and Cornell's studies, no preference for either novel or familiar stimuli followed brief familiarization and a small amount of response decrement.

These studies combine to support the hypothesis that novelty preference attenuates as length of familiarization and degree of response decrement decreases. Preference for familiar stimuli were not found, but it is argued that even the brief familiarization periods used may have been too long to produce that effect with the particular stimuli used. It is also conceivable that the measure of exploratory behavior used in those studies biased the results away from the familiarity preferences. The response measured in all of the studies mentioned above was visual fixation, which obviously is only one of the many potential forms of exploratory behavior, and which may not be particularly potent for infants 4 months or older.

For example, 3-month-olds are already capable of visually directed reaching for objects (although they typically miss the object) and by 4 months infants are capable of both reaching and grasping visible objects (Halverson, 1931; ~~Watson~~ and Lowry, 1967). Moreover, Fantz, Fagan and Miranda (1975) have reported that by 4 months of age visual processing has become both highly efficient and highly selective toward those "palpable" stimulus features relevant for behavior such as manipulation (and away from those features not relevant). In an multivariate study of exploratory behavior (McQuiston and Wachs, 1979) the frequency of visual exploration, though stable from 7 to 19 months, was consistently low both during sustained exploration of a single object and during a novelty preference test. On the other hand, the frequency of focused (visually guided) manipulation was consistently higher than visual fixation and the discrepancy between the two increased with age. Although the youngest infants in McQuiston and Wach's study were somewhat older than the oldest infants in the studies cited above, that difference is not large enough to ignore the possible prepotency of focused manipulation over visual fixation as a preferred form of exploration. Thus for older infants visual fixation may be a cursory form of exploration used to glean a general survey of those stimulus features calling for more detailed exploration. As a consequence of such rapid visual processing, the subjective uncertainty produced by even short amounts of familiarization



with a 2-dimensional stimulus (which would have few "palpable" features) would not be enough to motivate a return to that stimulus. However, a familiar stimulus might be preferred following interruption of the longer processing characteristic of detailed exploration with both hands and eyes.

In sum, it has been argued in this presentation that preferences for both familiar and novel stimuli can be found at any age (a) if the stimuli are complex relative to the age of the infant under study; (b) if testing for preference occurs both prior to and after habituation has been completed; and (c) if detailed rather than cursory forms of exploration are measured. With these points in mind, Hunter, Ross and Ames (in press) allowed some 12-month-old infants to reach a criterion of habituation while experimentally interrupting the focused manipulation of other 12-month-olds before habituation was complete. The stimuli were arrays of 5 toys which had been chosen as complex for that age on the basis of previous research (Ross, 1974). Following familiarization both groups were given a 10 minute test trial during which both the familiar array and an equivalent array were available. For half the infants in each group the familiar toys were placed in the same location as during the familiarization trial (familiar location) and the novel toys were placed in a novel location. For the other half the familiar toys were moved to the novel location and the novel toys were placed in the familiar location. Overall, infants in

the habituated group decreased responding with familiarization and subsequently preferred the novel toys, while interrupted infants maintained a high level of exploration in the time allowed them and subsequently preferred the familiar array. Thus, Hunter et al. (in press) provided the first evidence that under certain specifiable conditions both novelty and familiarity preferences can be found in infants older than 2 months.

An unexpected result in the Hunter et al. (in press) study was that for some infants the initial choice of which array to explore was influenced by the location of the arrays. The interrupted infants consistently returned to the familiar location and initially touched whichever toys had been placed there. If the toys were familiar they stayed in that location and continued to explore. If the toys were novel they left to enter the novel location where they found and explored the familiar toys. The location of the toys did not affect the behavior of the habituated infants, who contacted novel toys regardless of where those toys had been placed. In order to interpret these data, Hunter et al. suggested that the information differential between the interrupted and habituated groups led to differences both in which toys they preferred to explore and in their ability to find those toys. Habituated infants had obtained enough information about the properties of the toys (e.g., location, color, size, shape) to enable them to

compare the arrays on the basis of those properties and to approach the one that was most novel. Interrupted infants, however, had acquired much less information about the familiar toys and since much of that information could overlap between the novel and familiar arrays it was only partially valuable in helping distinguish between them. The one feature that never overlapped between the two arrays, however, was their location. Therefore, the interrupted infants may have returned to the familiar location because it represented the only cue that uniquely identified the familiar array. Once they re-established contact with the toys, the toys' properties were more clearly discernable and they either stayed in the familiar location if they recognized the toys as familiar or left if they recognized them as novel.

Although Hunter et al. (in press) focused on stimulus properties, the results could have been explained in terms of the infants' actions with the toys. Piaget (1954) suggested that infants in their first year construct representations of objects according to their sensorimotor interactions with those objects. Thus, interrupted infants may have moved toward the familiar location because that movement represented the only completed action that uniquely identified the familiar array. Once they re-established contact they could better identify the toys as familiar or novel on the basis of those properties of the toys that required action.

## Purposes of the present research

The purpose of the research described in this thesis was two-fold. First, since the experiment conducted by Hunter et al. (in press) has been the only one to report familiarity preferences in infants older than 2 months, replicating that research was essential. The second purpose was to extend the design of Hunter et al. to test hypotheses concerning novelty/familiarity preference and the interaction between stimulus complexity and familiarization time, to examine that interaction over age and to investigate different measures of exploratory behavior. Hunter et al. studied only one age (12-month-olds) who explored stimuli at only one complexity level (complex). In the present experiment 12-month-olds explored arrays of toys that were either simple (3 toys) or complex (5 toys) relative to their age, for either a brief period of time or until focused manipulation had habituated to a stringent criterion. These groups represented a test of the interaction between complexity and amount of familiarization as a determinant of exploratory preference. A group of 8-month-olds received only the 3-toy array with which they also were either habituated or interrupted prior to habituation. That group, for whom the 3-toy array was considered complex (rather than simple as it had been for the 12-month-olds), was included to

investigate the notion that effective complexity varies with respect to age. Following the familiarization trial all infants were offered a choice between the familiar and a novel array of toys in a 10 minute test trial. Both initial visual fixation and total focused manipulation were measured in order to compare preferences as a function of response type.

The following specific outcomes were expected:

1. Familiarization trial:

Infants who were habituated with a complex stimulus (8-month-olds/3 toys, 12-month-olds/5 toys) were predicted to take longer to reach criterion and to explore the toys than were infants who were habituated with a simple stimulus (12-month-olds/3 toys).

2. Test trial

Visual fixation. (a) Over all complexity levels and ages habituated infants should spend a higher proportion of time fixating a novel array than should interrupted infants.

(b) Habituated infants should show a visual preference for a novel array.

(c) Interrupted infants should show either an attenuated novelty preference or no preference for either the novel or familiar array.

Focused manipulation. (a) Compared to interrupted infants, infants in the habituated groups should spend a higher proportion of their time with a novel array. This difference

should be greater for infants familiarized with a complex array than for infants familiarized with a simple array.

(b) Habituated infants should show a preference for novel toys at both ages and with both the simple and the complex stimuli.

(c) Interrupted 8-month-olds and 12-month-olds familiarized with 5 toys should show a preference for familiar toys.

Infants familiarized with a simple stimulus (12-month-olds familiarized with 3 toys) should show either no preference or an attenuated preference for novel toys.

The relation between location and object exploration was less amenable to specific predictions. Certainly the results for the 12 months complex group were expected to replicate Hunter et al. (in press). However, predictions concerning the 8-month-old and 12 months simple groups were less clear. A tentative expectation for the 12 month-old simple stimulus group was that they should be less prone to returning to the familiar location following interruption since they had fewer features to process (or actions to complete) than did the 12 months complex group. The 8-month-olds might be expected to show a stronger tendency than 12-month-olds to return to the familiar location if the representation-by-action interpretation is correct. According to Piaget (1954) they would have a lesser understanding of the spatial organization of objects than 12-month-olds. If the perceptual features interpretation is correct the 8-month-olds

might be expected to show more random initial choice following interruption since they may be relatively less efficient at feature extraction.

## II. CHAPTER 2

### METHOD

The general plan of this experiment was to present two arrays of toys, each of which contained either three toys or five toys, to 8-month-old and 12-month-old infants and to measure the length of time each array was manipulated. Prior to this test half of the infants in each age X array-size group had been familiarized to the point that their responding had habituated while the other half had been familiarized but not habituated to one of the arrays. During the familiarization trial the array was placed in one of two locations. During the test trial the familiar toys either remained where they had been during the familiarization trial (and the novel toys were placed in a novel location) or the familiar toys were moved to a novel location (and the novel toys were placed in the location previously occupied by the familiar toys).



## Subjects

Subjects were chosen according to their age and their ability to locomote. Sixty-four infants aged 11.5 to 12.5 months and 32 infants aged 7.5 to 8.5 months all of whom could crawl or walk served as subjects. The infants were volunteered for the study by their parents in response to a printed request given to mothers in maternity wards of five local hospitals. An equal number of girls and boys took part in each group.

The records of fifteen infants (nine 12-month-olds and six 8-month-olds) were discarded due to equipment failure. An additional eight infants did not leave their mother to explore due to fussing (five 12-month-olds and three 8-month-olds) and four 8-month-olds did not leave their mothers because they could not crawl. Four 12-month-olds and three 8-month-olds explored during the familiarization trial but would not leave their mothers during the test trial. Six of these infants had been interrupted prior to habituation while one 12-month-old boy had been habituated. For all seven of these infants the familiar toys had been moved to a novel location and the novel toys placed in the familiar location.

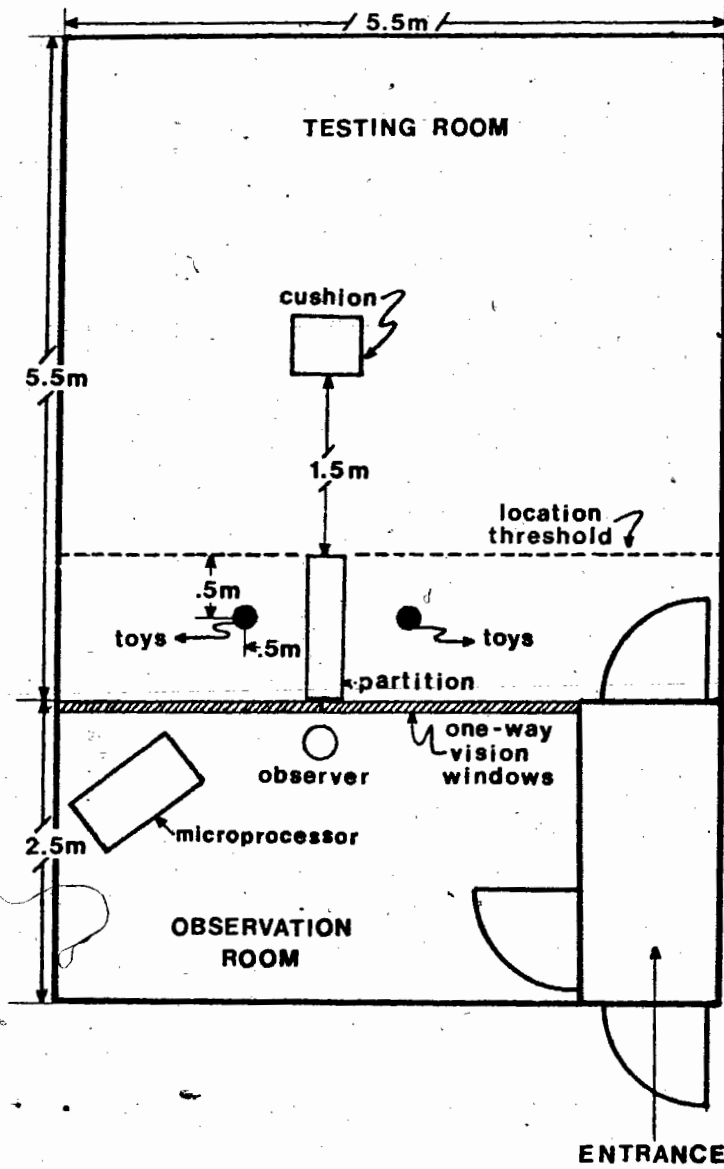
### Experimental environment and materials

A floor plan of the experimental environment is shown in figure 12. Testing was conducted in a single large room 5.5 x 8.0 meters. The room was carpeted but contained no furniture. One of the longer walls contained a one-way-vision window and was bisected by an opaque partition .91m high and .30m wide extended 1.22m from the wall. An imaginary line perpendicular to the partition and extending to the adjoining walls defined the boundaries of the areas which contained the toys. A cushion on which the mother sat was placed 1.5m away from, and directly in line with, the partition.

Seventeen commercially available toys were used as stimulus materials. All were brightly colored, most had moving parts and most were designed to provide auditory as well as visual and tactile stimulation. The toys were placed on either side of the partition approximately .5m behind the imaginary line defining toy areas. For the 8-month-olds the stimulus was a 3-toy array, while one group of 12-month-olds received 3 toys and the other group 5 toys. The use of the 3-toy array for both age groups was included to test the assumption that complexity level changes with age.

Figure 12

Diagram of Experimental Environment



## Procedure

On arriving, the mother and her child were escorted into a reception room where the aims and procedures of the experiment were explained and the mother signed a form indicating her consent for her child to take part in the research. From a set of color photographs of toys available for use in the experiment the mother identified any that her infant had at home.

For the familiarization trial one array of toys (either 3 toys or 5 toys, depending on the group) was placed on one side of the partition. All toys used were randomly selected from those the infant did not have at home. Toy placement was randomly determined and balanced among the infants within each group.

The experimenter led the mother and infant into the experimental room to start the familiarization trial. The mother was asked to sit on the cushion and to place the infant directly in front of her facing the toys. Beyond offering support when necessary she was asked to remain seated and to refrain from initiating any interaction with the infant or directing his/her behavior. She was instructed to listen for a tap on the window, at which time she released the infant to let him/her approach and explore the toys. On trial end (determined by individual criterion, described below) a tap on the window signaled the

mother to retrieve her infant, then carry him/her to the reception room for about one minute while the experimental room was arranged for the test trial.

To begin the test trial the mother carried the infant into the room and sat on the cushion as before. A tap on the window signaled her to turn her infant toward the toys but to keep the infant on her knee. Following 20 seconds the mother was signaled by another tap to place her infant on the floor directly in front of her. The 20 second delay was included to insure that both arrays were noticed before the infant approached the toys and to allow for a measure of visual fixation uncontaminated by time spent looking while approaching the toys.

During the test trial the familiar toys either remained where they had been during the familiarization trial and the novel toys were placed in the area on the side of the partition previously unoccupied by toys, or the familiar toys were placed in the new location and the novel toys were placed where the familiar toys had been. The duration of the test trial was 10 minutes, including the 20 second delay period.

### Response measures

The principal measure of exploratory behavior was focused manipulation of the toys. This was recorded whenever the infant touched a toy with his/her hands while simultaneously watching

the action of his/her hands. Measures of visual exploration without concurrent manipulation, entrance into the areas containing the toys and first toys touched (whether novel or familiar) were also recorded. Data were recorded continuously throughout the trials by an observer who pressed buttons connected to a PCM-12 micro-processor. In addition, the observer dictated an audio tape record of which toys the child was manipulating, so that the number of different toys touched could be calculated.

#### Trial-end criteria

The duration of the familiarization trial was controlled by the infants' behavior. For all infants the trial began with the first focused manipulation of a toy. The micro-processor was programmed to sum the duration of focused manipulation as the familiarization trial proceeded. For habituated infants the trial ended when an individually determined habituation criterion was reached. The criterion was two consecutive minutes in each of which the duration of focused manipulation was fifty percent or less of what it had been during the first minute. This criterion had the advantage of taking into account the children's own characteristic rate of exploration as it was based on their own level of responding in the first minute. In addition, the ending of the trial did not depend on a momentary

lapse of interest, but occurred only after two minutes of reduced interest. The exploration of the interrupted group was allowed to continue for only 60 seconds of accumulated focused manipulation or 160 seconds of total trial time, whichever came first. Sixty seconds was chosen with the aim of interrupting infants while their exploration was still high or increasing to the complex stimulus (5-toy for the 12-month olds and 3-toy for the 8-month-olds). The use of 160 seconds of total trial time prevented those infants in the interrupted group who explored only briefly from reaching the criterion set for the habituated groups, which in the minimal case could take 180 seconds (one minute to set the base level followed immediately by 2 minutes of less than fifty percent response).

Thus the overall design was a 3 x 2 x 2 x 2 factorial with groups (8-month-old/3 toys vs. 12-month-old/3 toys vs. 12-month-old/5 toys), degree of familiarity (habituated vs. interrupted), location (familiar toys in familiar area vs. familiar toys in novel area) and sex as the factors.

### Reliability

A second observer recorded the behavior of 60 infants. Inter-rater reliability as measured by the correlation between the results of the two observers and by percent agreement are discussed in Appendix A.

### III. RESULTS

The data for the familiarization trial consisted of scores for three response categories, namely: (a) total trial length; (b) total duration of focused manipulation; and (c) number of toys touched. For the test trial, the proportion of time spent visually fixating the novel array, the first-toy-touched/first-location-entered and the proportion of time spent in focused manipulation with toys in the novel array were the dependent measures.

Product moment correlation coefficients and percent agreement measures were obtained between the scores of two experimenters who independently recorded each response category. As shown in Appendix A, both measures for all response categories indicated high interobserver agreement.

#### Behavior during familiarization

The means and standard deviations for total trial length, total duration of focused manipulation and number of toys touched are presented in Table 1. Prior to statistical analyses the time scores (total trial length and total duration of focused manipulation) were subjected to transformation ( $\log X$ ) because of the known skewness of these measures (McCall, 1974). The means in Table 1 were retransformed back to the original



Table 1.

Behavior during the familiarization trial: Means and standard deviations for; Total Trial Length, Total duration of Focused Manipulation and Number of Toys Touched.

	Total Trial Length		Total Manipulation		No. of Toys Touched	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
<b>Habituated</b>						
8 months						
Males	393.5	(1.77)	186.8	(2.53)	2.5	(0.76)
Females	542.0	(1.42)	242.1	(2.54)	2.9	(0.35)
12 months simple						
Males	320.6	(1.43)	132.0	(1.82)	2.5	(0.76)
Females	359.1	(1.26)	177.2	(1.34)	2.9	(0.35)
12 months complex						
Males	423.2	(1.68)	200.1	(2.06)	4.0	(1.07)
Females	605.8	(1.83)	264.6	(2.06)	4.8	(0.46)
<b>Interrupted</b>						
8 months						
Males	87.5	(1.13)	60.0	(1.00)	1.9	(0.83)
Females	86.2	(1.27)	60.0	(1.00)	1.9	(0.64)
12 months simple						
Males	123.3	(1.37)	53.9	(1.19)	2.3	(0.71)
Females	101.6	(1.38)	49.4	(1.13)	1.9	(0.64)
12 months complex						
Males	110.7	(1.23)	58.6	(1.07)	3.1	(1.46)
Females	107.5	(1.34)	57.2	(1.15)	2.9	(0.99)

2

scale (seconds) and therefore many of them are not identical to the raw means. Further, the retransformed standard deviations cannot be interpreted in their usual manner. For example, a value one standard deviation above or below a mean would be obtained by multiplying or dividing that mean by its standard deviation rather than by adding or subtracting its standard deviation.<sup>2</sup>

The total trial length was determined by the behavior of the infants in accordance with the habituation and interruption criteria. For all habituated infants the familiarization trial lasted for an average of 429.6 seconds, while 101.9 seconds was the average trial length for all interrupted infants. In the interrupted groups, which had a dual criterion, 40 infants accumulated 60 seconds of focused manipulation (sixteen 8-month-olds, eleven 12-month-olds simple stimulus, thirteen 12-month-olds complex stimulus) and 8 were interrupted 160 seconds after their initial contact with the toys (five 12-month-olds simple stimulus, three 12-month-olds complex stimulus).

Focused manipulation occupied approximately half of the total trial time in both familiarization conditions, averaging 196.8 seconds for the habituated infants and 56.4 seconds for the interrupted infants.

As one feature of the criteria determining total trial length was that the duration of the trial could not overlap

between habituated and interrupted groups, that difference was not tested. For the same reason analyses were not performed on the differences between habituated and interrupted groups either in their durations of focused manipulation or in number of toys they touched. However, both total trial length and total duration of focused manipulation could differ among subgroups within each familiarization condition. These differences are discussed below. (Notice that within familiarization conditions, number of toys touched remained confounded by the fact that different subgroups received different number of toys. Consequently, number of toys touched was presented at the descriptive level).

Total trial lengths for habituated infants were analyzed in a 3 X 2 X 2 analysis of variance. There are 3 groups (8-month-olds, 12-month-olds simple stimulus and 12-month-olds complex stimulus), males and females, and 2 initial placements of the toys (to the left or to the right of the partition). Since this analysis revealed that the main effect of initial placement and all interactions involving that factor were not statistically significant, it was collapsed and a 3(groups) X 2 (sex) analysis of variance was carried out. The summary table for this analysis is given as Table 2.

As can be seen from Table 2 neither the second-order interaction nor the main effects of groups or sex reached accepted levels of statistical significance. Planned comparisons

Table 2.

Summary of Analysis of Variance of  
Total Trial Length for Habituated Groups.

Source	df	MS	F	<u>p</u>
Groups (G)	2	.7100	2.73	<.07
Sex (S)	1	.8560	3.29	<.08
G x S	2	.0705	<1	
Error	42	.2597		

Planned Comparisons for Groups

	8-months	12-months simple	12-months complex
Means	2.67	2.53	2.71
(retransformed)	(467.7)	(338.8)	(512.86)

Comparisons:

- (1) 8-months vs. 12-months simple  $F(1,42) = 5.95, p < .02$
- (2) 8-months vs. 12-months complex  $F(1,42) = 0.50, p < .50$
- (3) 12-months simple vs. 12-months complex  $F(1,42) = 10.37, p < .003$

performed on the groups factor indicated that the rate of habituation varied with complexity as predicted. That is, the 8-month-old and the 12-month-old complex stimulus groups, who did not reliably differ from one another, both required more time to complete habituation than did the 12-month-old simple stimulus group.

A 3(groups) X 2(sex) analysis of variance was used to analyze the total duration of focused manipulation for the habituated infants. (Preliminary analysis had indicated that initial placement of the toys could be dropped from the model). As shown in Table 3 no statistically significant effects were found. Planned comparisons revealed that the 12-month-old simple stimulus group spent less time on focused manipulation than did the 12-month-old complex stimulus group. However, in spite of having differed in total trial length, the difference in total durations of focused manipulation between the 8-month-old and 12-month-old simple stimulus groups was not significant.

Analyses of variance of the interrupted groups' data found no reliable main effects or interactions either for total trial length or for total duration of focused manipulation.

The use of different criteria for the habituated and interrupted groups ensured differences between them both in total trial length and in total duration of focused manipulation. To further determine the probable effect of

Table 3.

Summary of Analysis of Variance of  
Total Duration of Focused Manipulation  
for Habituated Groups.

Source	df	MS	F	P
Groups (G)	2	.9928	1.64	<.20
Sex (S)	1	1.3567	2.24	<.10
G x S	2	.0721	< 1	
Error	42	.6066		

Planned Comparisons between Groups

	8-months	12-months simple	12-months complex
Means	2.33	2.19	2.41
(retransformed)	(212.7)	(155.87)	(254.68)

Comparisons:

- (1) 8-months vs. 12-months simple  $F(1,42) = 2.82, p < .20$
- (2) 8-months vs. 12-months complex  $F(1,42) = 0.90, p < .35$
- (3) 12-months simple vs. 12-months complex  $F(1,42) = 6.92, p < .02$

interruption, the criteria applied to interrupted infants were applied to the habituation data of the habituated groups. Thirty-seven infants would have been interrupted after 60 seconds of focused manipulation (fifteen 8-month-olds, ten 12-month-olds simple stimulus, and twelve 12-month-olds complex stimulus) and eleven after 160 seconds of total trial time (one 8-month-old, six 12-month-olds simple stimulus and four 12-month-olds complex stimulus). These figures are comparable to those found in the interrupted groups (sixteen vs. zero, eleven vs. five, and thirteen vs. three for the 8-month-old, 12-month-old simple stimulus and 12-month-old complex stimulus groups respectively).

For the 8-month-olds, interruption would have occurred prior to their maximal level of exploration for 13 infants, at 100 percent of their peak response for 2 infants and would have reached criterion for 1 infant. Nine infants in the 12-month-old complex stimulus group would have been interrupted prior to their peak response, 3 at 85-100 percent of maximal exploration and 4 infants would have reached criterion. For 10 infants in the 12-month-old simple stimulus group interruption would have occurred at their peak response (100 percent) and 6 would have reached criterion. Thus, for the 21 of the 32 infants for whom the stimulus was complex relative to their age, exploration continued to increase beyond the interruption criteria. In contrast, none of the simple stimulus infants showed that

pattern. One might presume that interruption had a similar effect in the interrupted groups.

#### Behavior during the 10-minute test trial

The dependent measures for the test trial consisted of (a) the proportion of time spent fixating the novel array during the first 20-seconds of the trial, of (b) the first-toy-touched/first-location-entered and of (c) the proportion of time spent in focused manipulation with toys in the novel array. Analyses of these scores included both relative and absolute comparisons. Relative comparisons were concerned with differences among various subgroups and their interactive combinations irrespective of the magnitude of novelty or familiarity preference of any individual group (e.g., analysis of variance procedures). The absolute comparisons were intended to indicate whether a particular group exceeded chance novelty or familiarity preference irrespective of that group's standing relative to other groups (e.g., t-tests against an expected value of 50 percent). Throughout this section the term preference will always refer to a statistical deviation from an expected chance value. Absolute comparisons were carried out only for those subgroups that represented some a priori interest. For example, differential preferences were expected for the different groups (8-month-olds, 12-month-old simple stimulus, and 12-month-olds complex stimulus) under different



familiarization (habituation and interruption) and location (familiar toys in the familiar location and familiar toys in the novel location) conditions. Thus, each subgroup in the groups X familiarization X location matrix was tested against chance expectations. Conversely, sex and initial placement of toys, which essentially represented control factors in this experiment, were not included among the absolute comparisons.

Prior to analyses all proportion scores were transformed by  $\ln((\text{number of seconds spent with novel toys} + 1) / (\text{number of seconds spent with familiar toys} + 1))$  in order to overcome the correlation between means and standard deviations and to reduce heterogeneity of variance.

Preliminary analyses had indicated that initial placement of toys did not have a reliable effect on any of the dependent measures either by itself or in interaction with any other factor. Consequently, it is not included in the analyses presented below.

#### Vision alone

The retransformed vision alone means and standard deviations are shown in Table 4. The asterisks refer to the level of significance at which particular subgroups differed from chance response. These data were analyzed using  $3 \times 2 \times 2 \times 2$  analysis of variance with factors groups (8-month-olds vs. 12-month-olds simple stimulus vs. 12-month-olds complex

Table 4.

Mean vision alone proportions and standard deviations for the  
Groups X Familiarization X Location X Sex subgroups.

	F-F <sup>a</sup>		F-N <sup>b</sup>		Total	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
<b>Habituated</b>						
8 months						
Male	81	(.61)	64	(.71)		
Female	65	(.51)	70	(.67)		
Total	73***	(.68)	66*	(.68)	70***	(.66)
12 months simple						
Male	56	(.70)	52	(.65)		
Female	75	(.58)	75	(.55)		
Total	65*	(.67)	62*	(.65)	64**	(.66)
12 months complex						
Male	69	(.66)	57	(.58)		
Female	76	(.64)	81	(.67)		
Total	71**	(.64)	67*	(.69)	69***	(.67)
All subjects	70***	(.65)	65***	(.67)	67***	(.66)
<b>Interrupted</b>						
8 months						
Male	44	(.55)	60	(.73)		
Female	26	(.63)	38	(.68)		
Total	36*	(.63)	49	(.72)	43	(.69)
12 months simple						
Male	65	(.63)	51	(.65)		
Female	56	(.67)	58	(.65)		
Total	60	(.65)	55	(.64)	57	(.65)
12 months complex						
Male	49	(.77)	55	(.54)		
Female	52	(.66)	71	(.72)		
Total	50	(.71)	62	(.67)	56	(.69)
All subjects	49	(.69)	55	(.68)	52	(.52)

\* p .05

\*\* p .01

\*\*\* p .001

a. F-F denotes the location condition where the familiar array remained in the familiar location and the novel array was placed in the novel location.

b. F-N: The familiar array was moved to the novel location and the novel array was placed in the familiar location.

stimulus), familiarization (habituated vs. interrupted), location (familiar toys in the same location vs. familiar toys moved to the novel location and novel toys in the location previously occupied by the familiar toys) and sex. The summary table for the analysis is presented in Table 5.

Neither the fourth- nor any of the third-order interactions were significant. The main effect of groups, location and sex were also not significant. The reliable main effect of familiarization indicates that overall, the habituated infants spent a greater proportion of their time visually exploring the novel array during the first 20 seconds of the test trial than did interrupted infants. However, the significant groups X familiarization interaction implies that the familiarization effect was stronger for some groups than for others. In order to access this interaction more thoroughly, analyses of the simple effects of familiarization and groups were undertaken (see figure 13).

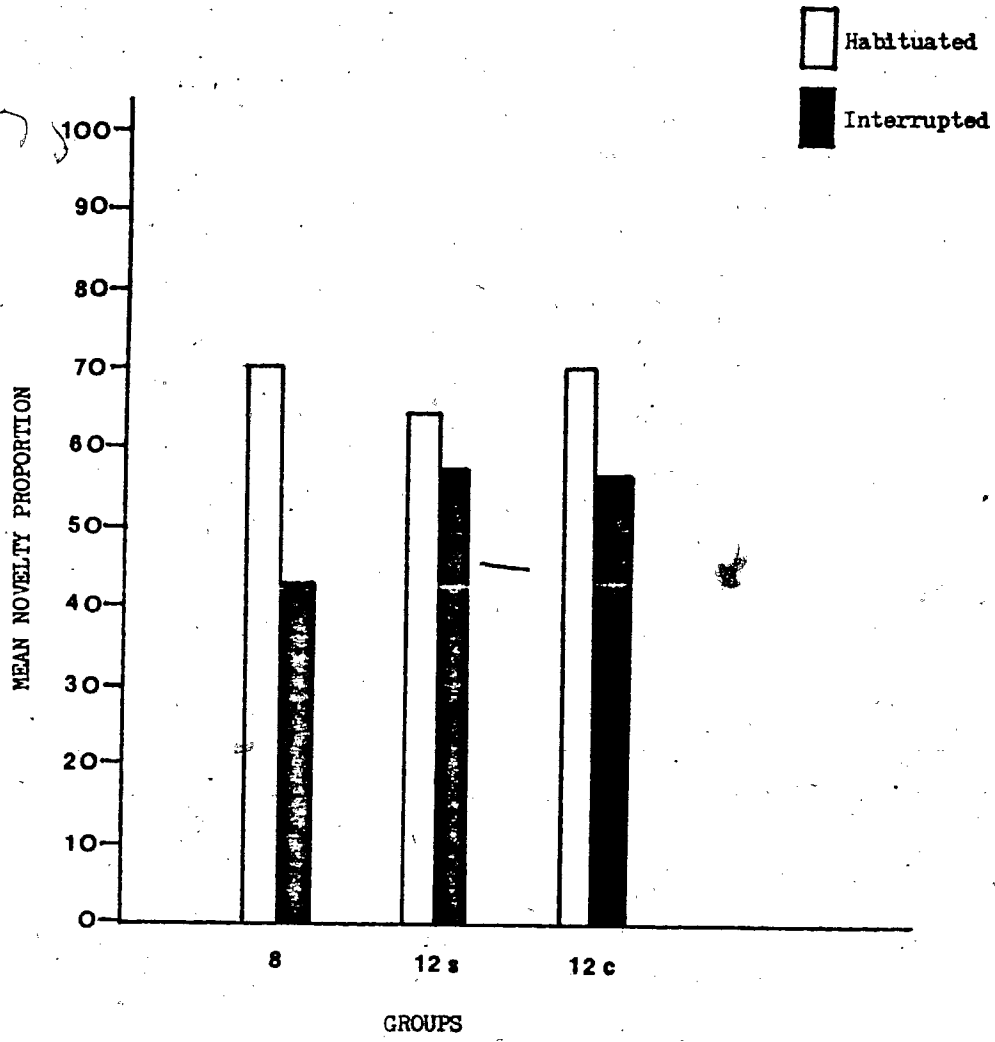
Both the habituated 8-month-old and the habituated 12-month-old complex stimulus groups spent significantly higher proportions of time looking at the novel toys than did their interrupted counterparts ( $F(1,72) = 23.27, p < .001$  and  $F(1,72) = 5.84, p < .05$  respectively). The difference between habituated and interrupted 12-month-old simple stimulus groups was not reliable,  $F(1,72) = 1.26, p < .27$ .

Table 5.

Summary of analysis of variance of  
Vision Alone proportions.

Source	d f	MS	F	p
Groups (G)	2	0.59	1.38	
Familiarization (F)	1	10.09	23.50	.001
Location (L)	1	0.03	0.06	
Sex (S)	1	0.04	0.93	
G x F	2	1.55	3.63	.02
G x L	2	0.24	0.55	
F x L	1	1.38	3.22	.09
G x S	2	2.89	6.74	.002
F x S	1	2.02	4.72	.03
L x S	1	1.68	3.91	.07
G x F x L	2	0.61	1.42	
G x F x S	2	0.13	0.29	
G x L x S	2	0.08	0.21	
F x L x S	1	0.19	0.44	
G x F x L x S	2	0.45	1.05	
Error	72	0.43		

Figure 13  
Groups X familiarization interaction.  
( Vision alone )



Simple effects analysis of familiarization found no difference among the habituated groups in amount of time spent visually exploring a novel array ( $F(2,72) = 1.74, p < .20$ ) while the interrupted groups were found to differ,  $F(2,72) = 5.33, p < .007$ ). This difference was due to the interrupted 8-month-olds spending less time visually exploring a novel array than either the interrupted 12-month-olds simple stimulus ( $F(1,72) = 6.63, p < .02$ ) or the interrupted 12-month-olds complex stimulus ( $F(1,72) = 5.78, p < .02$ ). The interrupted 12-month-old groups did not reliably differ from one another.

Thus, the hypothesis that habituated infants would spend more time looking at a novel array than would interrupted infants was generally supported. Further, as shown in Table 4, the overall pattern of preferences was clearly in accordance with prediction. Habituated infants showed an overall visual preference for the novel toys, while no preference for either novel or familiar toys was shown by interrupted infants. Inspection of the various subgroups reveals that while each habituated subgroup taken separately preferred the novel array, that preference was not shown by any of the interrupted subgroups. Indeed, the interrupted 8-month-olds in the familiar toys - familiar location condition showed a preference for visually exploring the familiar array. Notice that although the relative analysis had found no difference between habituated and interrupted 12-month-old simple stimulus groups in their

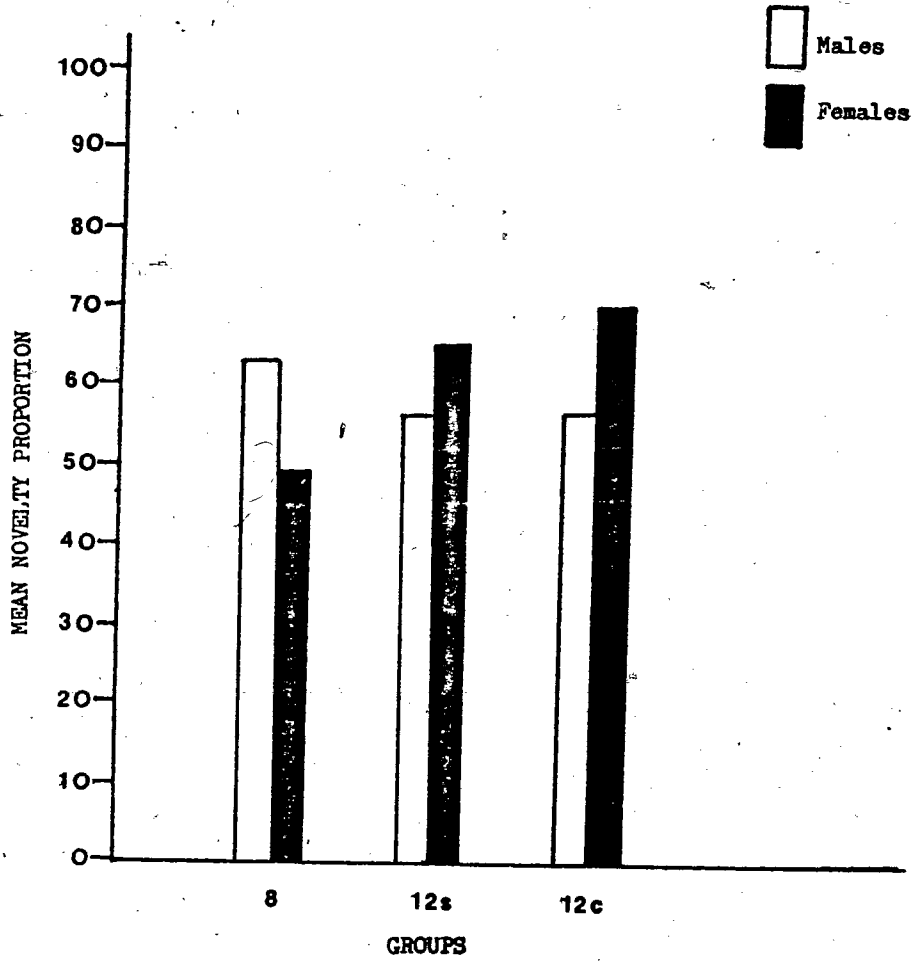
proportions of time spent visually exploring the novel array, the absolute analysis showed that they did differ as expected in their preferences, i.e. following habituation they showed a preference for the novel array, while no preference for either array followed interruption.

Two unexpected results from the analysis of the vision alone data included a groups X sex interaction and a familiarization X sex interaction.

The groups X sex interaction is illustrated in figure 14. Analysis of the simple effects of groups for each sex indicated differential looking times for females as a function of group membership ( $F(2,72) = 7.01, p < .002$ ) but no differences among the groups of males ( $F(2,72) = 1.12, p < .35$ ). Eight-month-old females spent less time looking at the novel array than females in either the 12-month-old simple stimulus group ( $F(1,72) = 7.5, p < .008$ ) or the 12-month-old complex stimulus group ( $F(1,72) = 15.32, p < .001$ ). The 12-month-old females did not significantly differ from one another ( $F(1,72) = 1.0$ ).

Separate tests of the difference between male and female infants looking scores for each groups revealed that 8-month-old males visually explored a novel array more than 8-month-old females ( $F(1,72) = 5.81, p < .02$ ) but that in the 12-month-old complex stimulus group, males spent less time exploring novel toys than females ( $F(1,72) = 5.83, p < .02$ ). No difference between males and females was found for the 12-month-old simple stimulus

Figure 14  
Groups X sex interaction  
( Vision alone )





group ( $F(1,72) = 2.78, p < .10$ ).

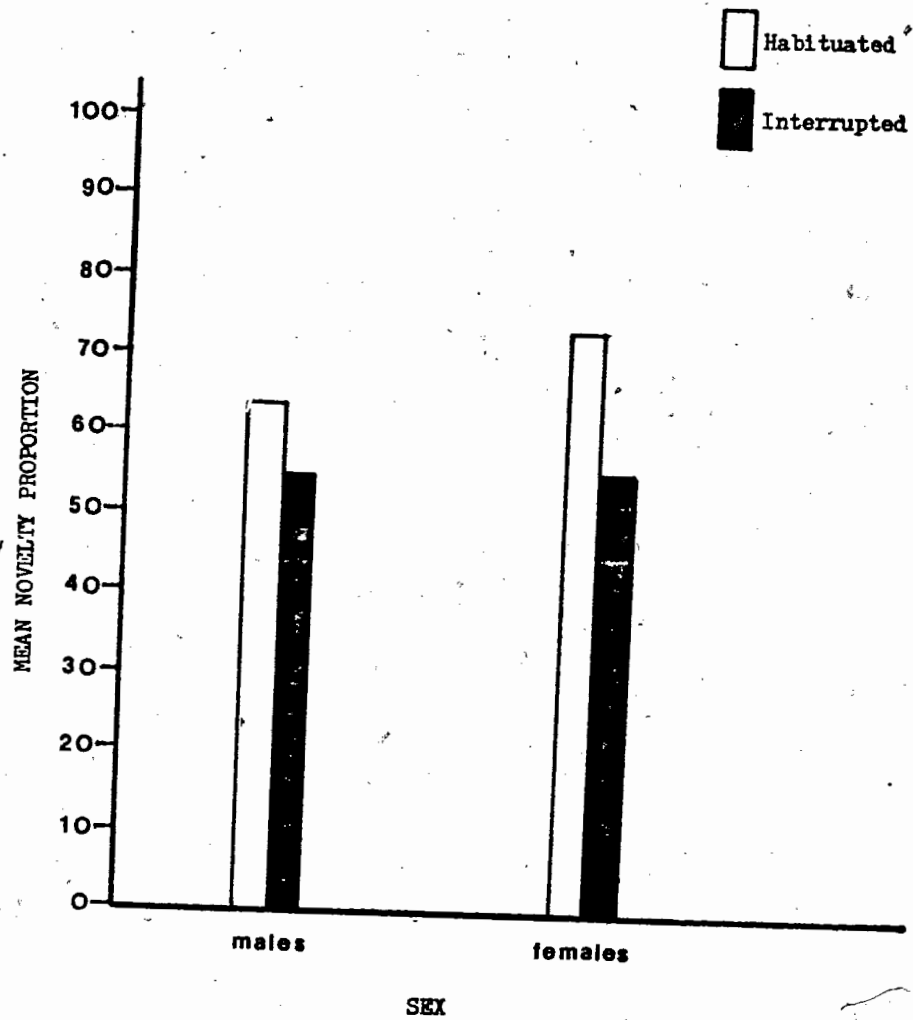
Simple effect analysis of sex for each familiarization condition showed that habituated females visually explored a novel array to a greater extent than did habituated males ( $F(1,72) = 4.93, p < .03$ ; see figure 15). Males and females did not differ following interruption,  $F(1,72) = 1.0$ . Nevertheless, the predicted difference between the two familiarization conditions was supported for each sex. Both males and females looked longer at a novel array following habituation than they did following interruption ( $F(1,72) = 3.98, p < .05$  and  $F(1,72) = 24.69, p < .001$  for males and females respectively).

The reason for the obtained sex differences is unclear. Further, given the notorious inconsistency of such differences in the habituation literature (cf. Caron et al., 1977) I hesitate to make much of them except to note that they do not override the strong support found for the pattern of predicted results.

#### First-toy-touched/First-location entered

The initial choice of which array to explore could have been determined by the novelty-familiarity of the toys or by the novelty-familiarity of their location. In order to estimate and analyze the separate effects of these variables a log linear analysis with maximum likelihood estimation was performed. Likelihood ratio tests were carried out to compare differences

Figure 15  
Familiarization X sex interaction.  
( Vision alone )



between the various subgroups and to compare each subgroup separately with chance expectations. (Notice that chance expectation is indicated by the value 0.0 in this analysis). These comparisons were made both for toy and location choices considered simultaneously and separately for each.

Preliminary analyses had indicated that neither the main effect of sex nor any interaction including sex were significant. Consequently, sex was dropped from the analyses and the model revised to include only the factors groups and familiarization.

The raw data and the estimated effects are presented in Table 6. Prior to analysis the cell frequencies were transformed by  $(X + .5)$  in order to stabilize estimates based on zero frequencies. The likelihood tests, however, were carried out on the raw frequencies.

As shown in Table 7, neither the groups X familiarization interaction nor the main effect of groups were reliable for any of the models tested. The significant main effect of familiarization for all models is due to habituated infants making initial contact with a novel toy and entering first a novel location more often than did interrupted infants. Moreover, as shown in Table 6 the habituated infants showed a statistical preference for the novel toys (and no preference for either location), while interrupted infants showed no preference for either novel or familiar toys but an overall preference for

Table 6.

Initial choice frequencies and log linear estimates of toy and location parameters.

	N-Location N-Toys	F-Location F-Toys	N-Location F-Toys	F-Location N-Toys
<b>Habituated</b>				
8 months	7	1	2	6
12 months simple	7	1	1	7
12 months complex	8	0	1	7
<b>Interrupted</b>				
8 months	1	7	4	4
12 months simple	4	4	3	5
12 months complex	3	5	1	7

Log linear estimates

	Location	Toys
<b>Habituated</b>		
8 months	0.33	1.28**
12 months simple	0.00	1.61**
12 months complex	0.61	2.22***
Total	0.39	2.00***
<b>Interrupted</b>		
8 months	- 0.80	- 0.80
12 months simple	- 0.23	0.23
12 months complex	- 1.03*	0.57
Total	- 0.69*	0.00

\*  $p < .05$   
 \*\*  $p < .01$   
 \*\*\*  $p < .001$

a. A negative number indicates a familiarity effect and a positive number indicates a novelty effect. A value of 0.0 indicates that room and toy effects are either equally present or absent.

Table 7-

Likelihood ratio tests of first  
toy touched and first location entered.

Source	d f	Likelihood Ratio $\chi^2$	P
Groups (G)			
Toys	2	4.92	.09
Location	2	0.37	
Toys & Location	4	5.11	
Familiarization (F)			
Toys	1	14.38	.001
Location	1	5.40	.03
Toys & Location	2	22.14	.001
G x F			
Toys	2	0.67	
Location	2	2.29	
Toys & Location	4	2.50	

the familiar location.

Although each group behaved in a manner similar enough to preclude the groups factor from showing up in the relative analysis, that factor did make a difference in terms of the location preference of interrupted infants. That is, while interrupted infants in each group showed a tendency to first enter the familiar location, only the 12-month-old complex stimulus group did so with enough regularity to result in a statistical preference for that location.

Thus, the first toy contacted by habituated infants tended to be in the novel array regardless of the area that contained it. On the other hand, infants in the interrupted groups either made inconsistent initial choices (e.g., 8-month-olds and 12-month-olds simple stimulus) or first entered the area that had contained toys during the familiarization trial and made initial contact with whatever toys were found there (e.g., 12-month-olds complex stimulus).

#### Focused manipulation

Focused manipulation scores were analyzed in a 3(groups) X 2(familiarization) X 2(location) X 2(sex) X 5(blocks) mixed analysis of variance with repeated measures on blocks. The blocks factor was included to investigate the pattern of exploration over the course of the test trial. A block was defined as one-fifth the total duration of focused manipulation

occurring during the test trial. For each successive block the proportions of time spent with toys from the novel array was calculated (and transformed). For example, an infant who explored for 4 minutes during the test trial would obtain 5, 48-second blocks ( $240/5 = 48$ ) and therefore, 5 scores based on proportions calculated for each successive 48 seconds of exploration. The use of blocks defined in this manner rather than simply dividing the total trial into real time units (e.g., 5, 2-minute segments) was prompted by noting that infants often showed the same pattern of exploration over time but that they did so at different rates. The consequence was a severe subject X "segments" interaction that resulted in a less efficient and less powerful F test for all within subject sources of variance. Further, using blocks as defined above ensured that proportions for each block for a particular subject were based on the same total number of seconds of focused manipulation. If real time units are used, proportion scores could be based on numbers of seconds ranging from zero to the total number of seconds comprising the particular unit used (e.g., 120 seconds if 2-minute segments were used). Obviously, scores based on few seconds are less reliable than those based on larger number of seconds.

Preliminary analysis indicated that sex was not a significant main effect nor did it interact with any other factors. As a result, the analyses presented below included only

the factors of groups, familiarization, location and blocks. The retransformed means and standard deviations and the absolute analysis are presented in Tables 8 and 9.

Analysis of the average covariance matrix for the blocks factor indicated that the homogeneity of covariance assumption was not met (Table 10). Therefore, the Greenhouse-Geisser epsilon was calculated and the degrees of freedom for the within subjects sources of variance were adjusted accordingly. The source table for the analysis of variance of focused manipulation is presented as Table 11. The main effects of groups and familiarization were both significant. However, the groups X familiarization interaction qualifies the separate interpretation of either factor. Simple effects analyses of groups and familiarization were undertaken in order to access this interaction more thoroughly (see figure 16).

Separate tests of the difference between habituated and interrupted infants for each group showed that both the 8-month-old and the 12-month-old complex stimulus groups spent significantly more time exploring toys in the novel array following habituation than they did following interruption ( $F(1,84) = 11.77, p < .001$  and  $F(1,84) = 9.64, p < .003$  for the 8-month-old and 12-month-old complex stimulus groups respectively). A tendency in the same direction by the 12-month-old simple stimulus group did not reach accepted levels of significance,  $F(1,84) = 3.05, p < .09$ . To analyze the simple



Table 8  
 Mean focused manipulation proportions and standard deviations for the  
 groups X familiarization X location X blocks subgroups.

	Blocks											
	1	2	3	4	5	Total						
	F-F	F-N	F-F	F-N	F-F	F-N	F-F	F-N	F-F	F-N		
<b>Habituated</b>												
8 months	.95**	.88	.97***	.95**	.96**	.95**	.88	.88	.89	.92*	.94***	.92***
SD	.93	.97	.78	.94	.85	.94	.96	.95	.95	.94	.93	.93
12 months simple	.91*	.95*	.94**	.90	.97***	.94*	.91*	.98**	.78	.98***	.92***	.96***
SD	.94	.94	.85	.96	.80	.91	.94*	.58	.97	.58	.90	.90
12 months complex	.98***	.93*	.98***	.91	.96**	.94*	.93*	.88	.78	.81	.96***	.90**
SD	.56	.95	.56	.95	.82	.95	.91	.91	.96	.97	.97	.92
Total	.95***	.93***	.97***	.92***	.96***	.94***	.91**	.93***	.83**	.93***	.94***	.93***
SD	.90	.95	.78	.95	.81	.93	.94	.91	.95	.93	.91	.92
<b>Interrupted</b>												
8 months	.07*	.53	.04***	.48	.03***	.36	.04*	.17	.04**	.13	.04***	.31
SD	.94	.99	.80	.98	.60	.98	.75	.95	.71	.97	.85	.93
12 months simple	.53	.56	.39	.71	.42	.61	.78	.50	.97**	.88	.69	.67
SD	.98	.97	.97	.97	.98	.92	.98	.92	.72	.95	.90	.77
12 months complex	.13	.94**	.07**	.72	.08*	.08*	.09*	.07**	.12	.08*	.10**	.32
SD	.95	.93	.86	.96	.93	.72	.95	.94	.94	.95	.89	.86
Total	.19**	.73	.11***	.64	.11***	.29	.18**	.20**	.35	.31	.17**	.43
SD												
All subjects	.69	.86	.66	.82	.64	.72	.60	.65	.62	.71	.64	.76
SD	.97	.97	.97	.96	.97	.97	.97	.96	.97	.97	.97	.95

\* p < .05  
 \*\* p < .01  
 \*\*\* p < .001

Table 9

Mean focused manipulation proportions and standard deviations for the groups X familiarization X blocks subgroups.

	Blocks					Total	
	1	2	3	4	5		
<b>Habituated</b>							
8 months	$\bar{X}$ SD	.92** .95	.96** .89	.95** .90	.88* .95	.90** .94**	.93*** .93***
12 months simple	$\bar{X}$ SD	.93** .93	.93** .92	.96** .87	.96** .88	.93** .94	.94*** .91
12 months complex	$\bar{X}$ SD	.93** .89	.96** .92	.96** .90	.91** .93	.79 .96	.93*** .91
Total	$\bar{X}$ SD	.94*** .93	.95*** .90	.95*** .89	.92*** .93	.89*** .95	.94*** .91
<b>Interrupted:</b>							
8 months	$\bar{X}$ SD	.22 .98	.16 .96	.10* .96	.08** .91	.07** .94	.12*** .93
12 months simple	$\bar{X}$ SD	.54 .97	.55 .97	.52 .96	.64 .95	.94** .89	.68 .85
12 months complex	$\bar{X}$ SD	.61 .97	.31 .96	.08** .94	.08** .94	.10* .94	.18* .88
Total	$\bar{X}$ SD	.45 .98	.32 .97	.18** .96	.19** .95	.33 .97	.29* .93
All subjects	$\bar{X}$ SD	.79 .97	.75 .97	.68 .97	.63 .97	.67 .97	.74 .96

\*  $p < .05$   
 \*\*  $p < .01$   
 \*\*\*  $p < .001$

Table 10  
Average covariance matrix for blocks

	Blocks				
	1	2	3	4	5
1	9.168	6.390	2.891	-.417	-2.108
2		7.304	4.530	-.225	-2.042
3			6.508	2.852	.212
4				7.068	5.077
5					7.509

degrees of freedom 13  
 chi-squared value 209.7742  
 probability value .001  
 greenhouse-seisser E .4687

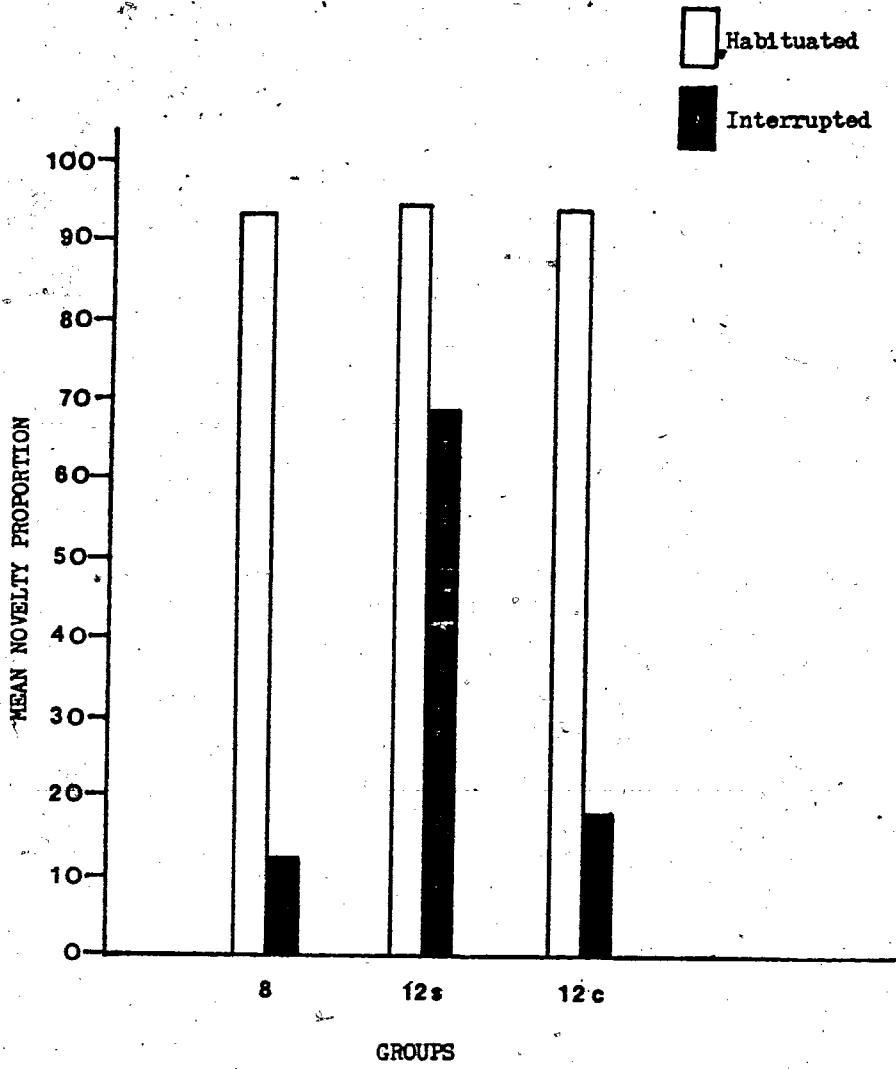
Table 11

Summary of analysis of variance of  
Focused Manipulation proportions

Source	d f	MS	F	P
Between subjects				
Groups (G)	2	101.25	7.04	.002
Familiarization (F)	1	1556.03	108.24	.001
Location (L)	1	38.95	2.71	
G x F	2	74.66	5.19	.008
G x L	2	7.71	0.54	
F x L	1	60.07	4.18	.04
G x F x L	2	36.91	2.57	.08
Error	84	14.36		
Within subjects				
Trials (T)	1.87	9.75	1.68	
G x T	3.75	17.45	3.01	.03
F x T	1.87	11.86	2.05	
L x T	1.87	2.86	0.46	
G x F x T	3.73	5.63	0.97	
G x L x T	3.75	2.48	0.43	
F x L x T	1.87	25.17	4.34	.02
G x F x L x T	3.75	4.62	0.80	
Error	157.49	5.79		

Figure 16

Groups X familiarization interaction.  
( Focused manipulation )



effects of groups, separate tests of the differences among groups for each familiarization condition were performed. There were no reliable differences among the habituated groups,  $F(2,84) = 1.0$ . A significant difference among the interrupted groups, ( $F(2,84) = 4.55, p < .02$ ) suggested that the interrupted 12-month-old simple stimulus group spent more time exploring novel toys than either the 8-month-old or the 12-month-old complex stimulus group. However, post hoc comparisons found no difference between any of the pairs of groups when the alpha level was corrected to account for multiple (three) comparisons.

Thus, there was strong support for the predicted relationship between amount of familiarization and subsequent time spent exploring novel toys. Habituated infants spent more time, overall, exploring novel toys than did interrupted infants. Further, the significant groups X familiarization interaction showed that this effect was attenuated when the familiarized stimulus was simple. The more rigorous prediction that the different groups would show different preferences as a function of amount of previous familiarization was also supported. As shown in Table 9, habituated infants in each group preferred to explore toys in the novel array, while toys in the familiar array were preferred by the interrupted 8-month-olds and the interrupted 12-month-old complex stimulus group. Interrupted 12-month-old simple stimulus infants spent more time with toys in the novel array but did not show a reliable

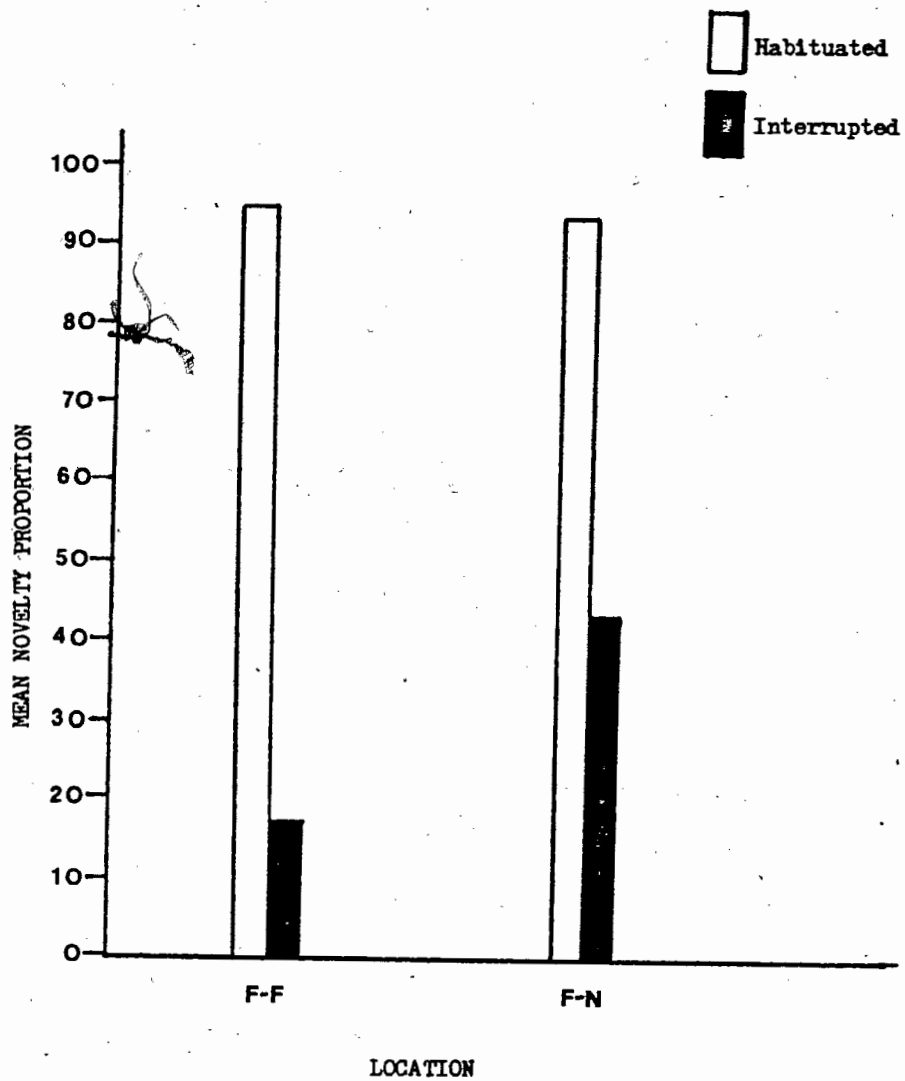
preference.

Location did not, overall, affect the amount of time spent exploring the toys. The significant familiarization by location interaction indicates that when the familiar toys were moved to the novel location and the novel toys placed in the familiar location, the magnitude of the difference between habituated and interrupted infants was attenuated. Nevertheless, simple effects analysis of familiarization (see figure 17) found habituated and interrupted infants to differ reliably in their proportions of time spent with novel toys in both location conditions ( $F(1,84) = 15.49, p < .001$  and  $F(1,84) = 6.98, p < .01$  for the familiar toy-familiar location and familiar toy-novel location conditions respectively). As well, the effects of location were not reliable for either the habituated infants ( $F(1,84) = 1.0$ ) or the interrupted infants ( $F(1,84) = 1.36, p < .25$ ).

The preference of the interrupted infants differed with respect to location (Table 8). When the familiar toys remained in the same location as during familiarization, the interrupted infants preferred the familiar toys. However, when the familiar toys were moved to a novel location interrupted infants did not prefer either array of toys. Habituated infants preferred novel toys in both location conditions.

Although the third-order interaction between groups, familiarization and location did not reach accepted levels of

Figure 17  
Familiarization X location interaction.  
( Focused manipulation )





statistical significance, the absolute analysis showed that the effect of location on the preferences of interrupted infants did differ among groups (Table 8). That is, the pattern consisting of a preference for familiar toys when they remained in the familiar location and no preference for either novel or familiar toys when the familiar toys were moved to a novel location held only for interrupted 8-month-old and 12-month-old complex stimulus groups. The interrupted 12-month-old simple stimulus infants did not prefer either array in either location condition.

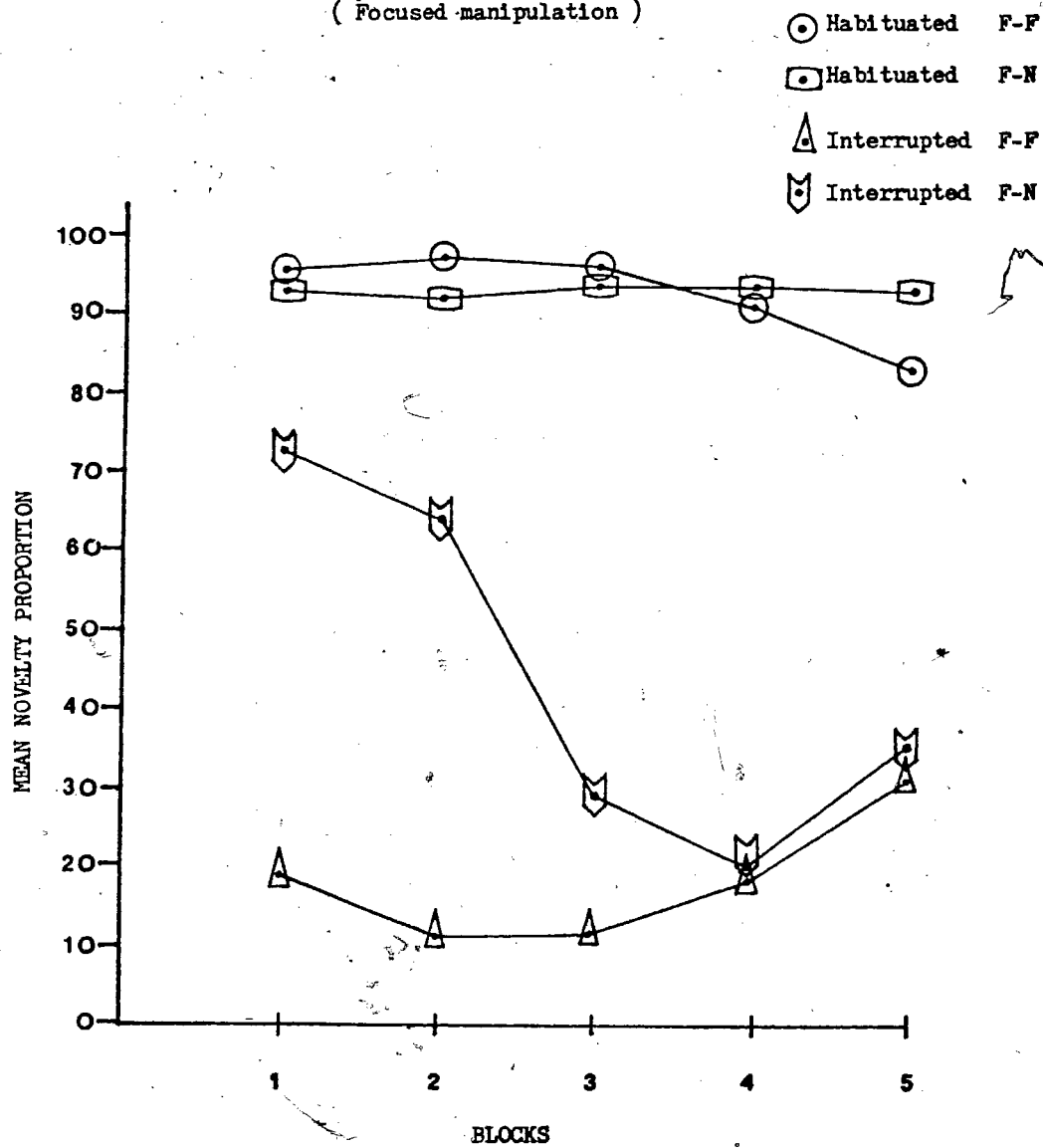
The differential effect of location for habituated and interrupted infants is consistent with the results obtained from the initial choice analysis. Recall that habituated infants sought out and first contacted novel toys regardless of the location of those toys. Their overall preference for toys in the novel array in both location conditions indicates that they continued to explore the novel toys throughout the 10-minute test trial. On the other hand, interrupted 8-month-old and 12-month-old complex stimulus infants went most often to the familiar location regardless of which toys were there. As a result their proportion scores differed according to which toys were in the familiar location. If the familiar toys remained in the familiar location they showed an overall preference for those toys; a result that suggests they continued to explore toys in the familiar array over most of the test trial. If the

novel toys were in the familiar location, however, essentially no preference was shown for either array. Therefore, they must have left the familiar location in order to find and explore the familiar toys (which were in the novel location). Otherwise they would have shown an overall preference for toys in the novel array. The significant familiarization X location X trials interaction indicates that this was in fact the case. In order to investigate this interaction more closely, analyses of the familiarization X location interaction at each level of blocks were carried out. (It should be noted that because of heterogeneity of covariance between pairs of blocks, 3-way (groups X familiarization X location) analyses of variance were performed at each block and the separate within-groups mean squares used as error terms for testing the simple familiarization X location effects.)

The means for each familiarization X location subgroup at each block are plotted in figure 18. Significant familiarization X location interactions obtained at block 1 ( $F(1,84) = 6.02$ ,  $p < .02$ ) and at block 2 ( $F(1,84) = 10.62$ ,  $p < .002$ ) were due to interrupted infants spending more time exploring the familiar array when it remained in the familiar location than when it was moved to a novel location ( $F(1,84) = 8.71$ ,  $p < .005$  and  $F(1,84) = 11.39$ ,  $p < .001$  for blocks 1 and 2 respectively), while habituated infants spent similar amounts of time exploring the novel array in both location conditions at both blocks. For

Figure 18

Familiarization X location X blocks interaction.  
( Focused manipulation )



blocks 3 through 5, location did not differentiate between either habituated or interrupted infants' exploration. Thus, during the early part of the test trial, moving the familiar toys to a novel location attenuated the difference between the interrupted and habituated infants. Nevertheless, even by block 2 that difference, though not as large as later in the trial, was still reliable,  $F(1,84) = 4.24, p < .05$ . The amount of time spent exploring novel toys for habituated and interrupted infants who received the familiar toys in the familiar location significantly differed from one another throughout the test trial.

The familiarization X location X blocks interaction for each of the three groups are shown in figures 19, 20 and 21. Although the patterns are similar enough to have precluded a 4-way groups X familiarization X location X blocks interaction, these figures are illustrative of (a) the overall groups X blocks interaction, and of (b) the differences in patterns of preferences for the three groups.

The general decrease in time spent exploring novel toys by the familiarization X location subgroups in 8-month-olds and 12-month-old complex stimulus groups as opposed to the general increase shown by the 12-month-old simple stimulus subgroups resulted in the reliable groups X blocks interaction shown in figure 22. Significant differences between groups at block 4 ( $F(2,84) = 6.05, p < .003$ ) and at block 5 ( $F(2,84) = 12.78, p < .001$ )

Figure 19

Familiarization X location X blocks interaction for 8 month-olds.  
( Focused manipulation )

- Habituated F-F
- ◻ Habituated F-N
- △ Interrupted F-F
- ◊ Interrupted F-N

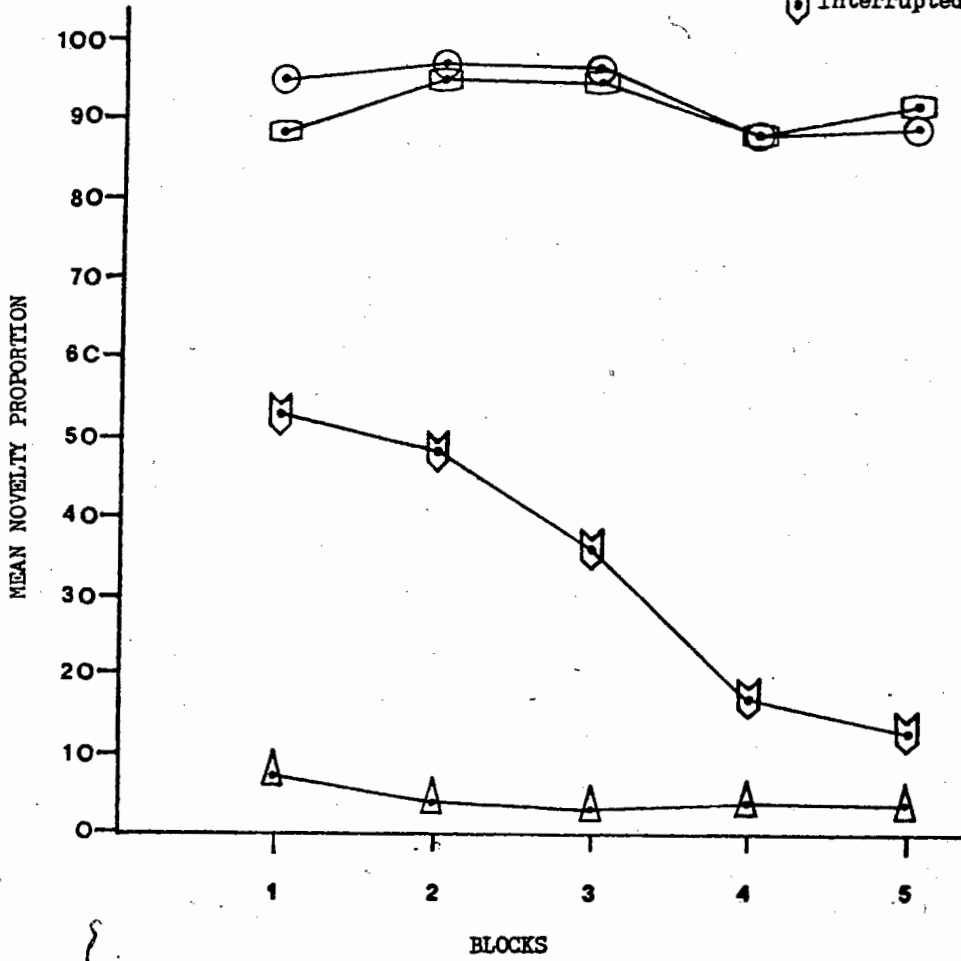


Figure 20

Familiarization X location X blocks interaction for 12 months simple.  
( focused manipulation )

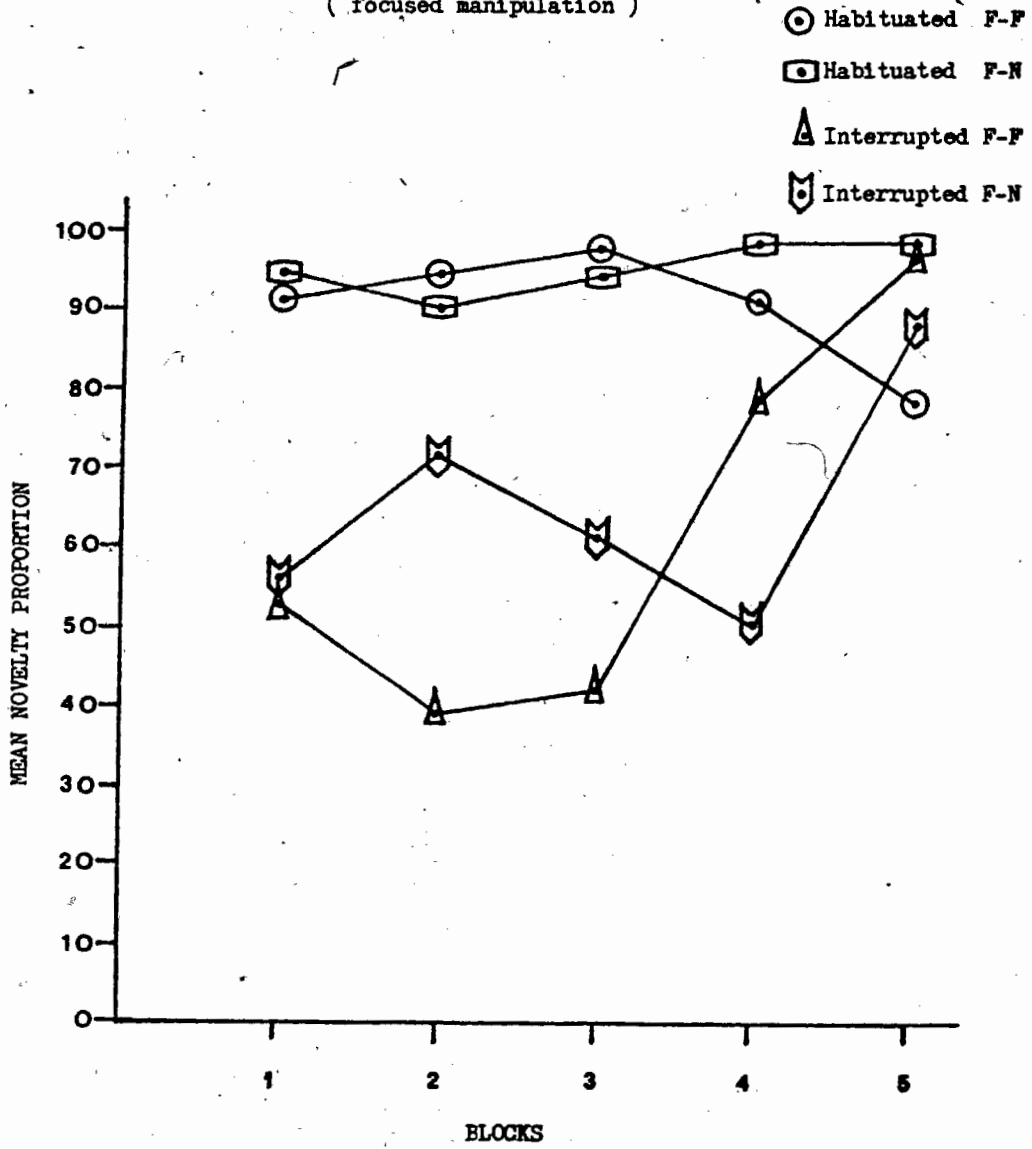


Figure 21

Familiarization X location X blocks interaction for 12 months complex.  
( Focused manipulation )

- Habituated F-F
- ◻ Habituated F-N
- △ Interrupted F-F
- ◻ Interrupted F-N

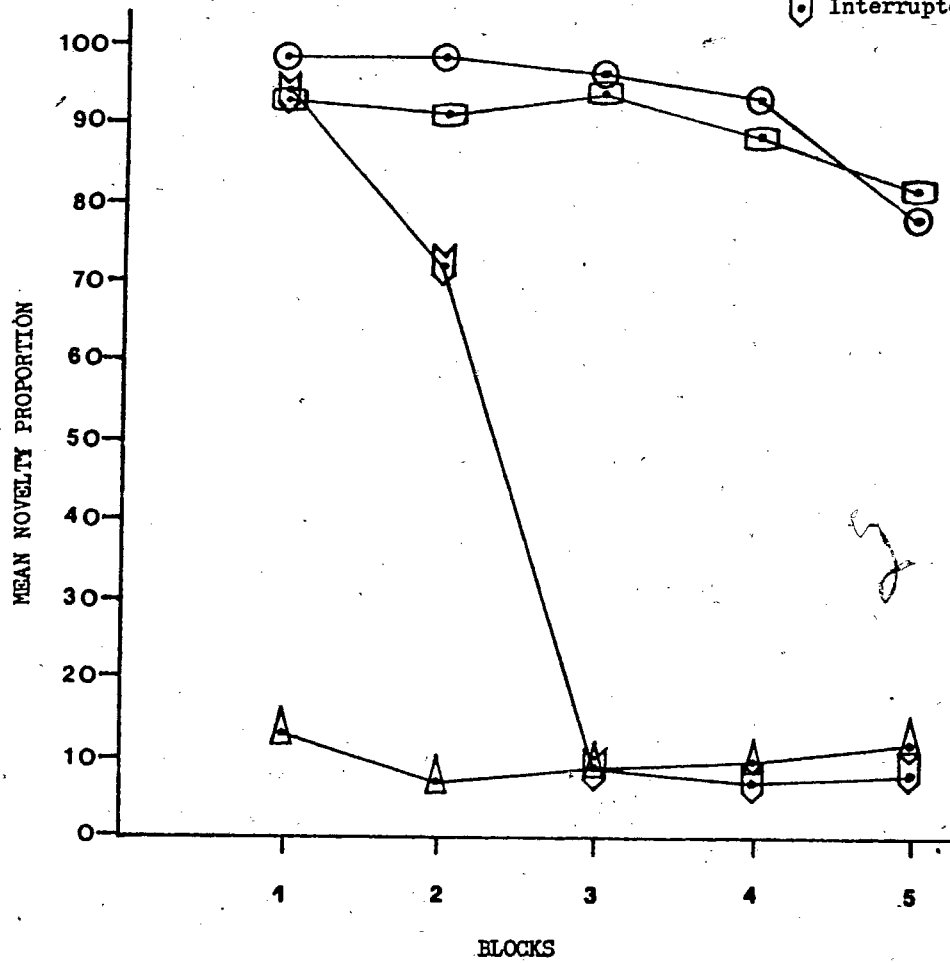
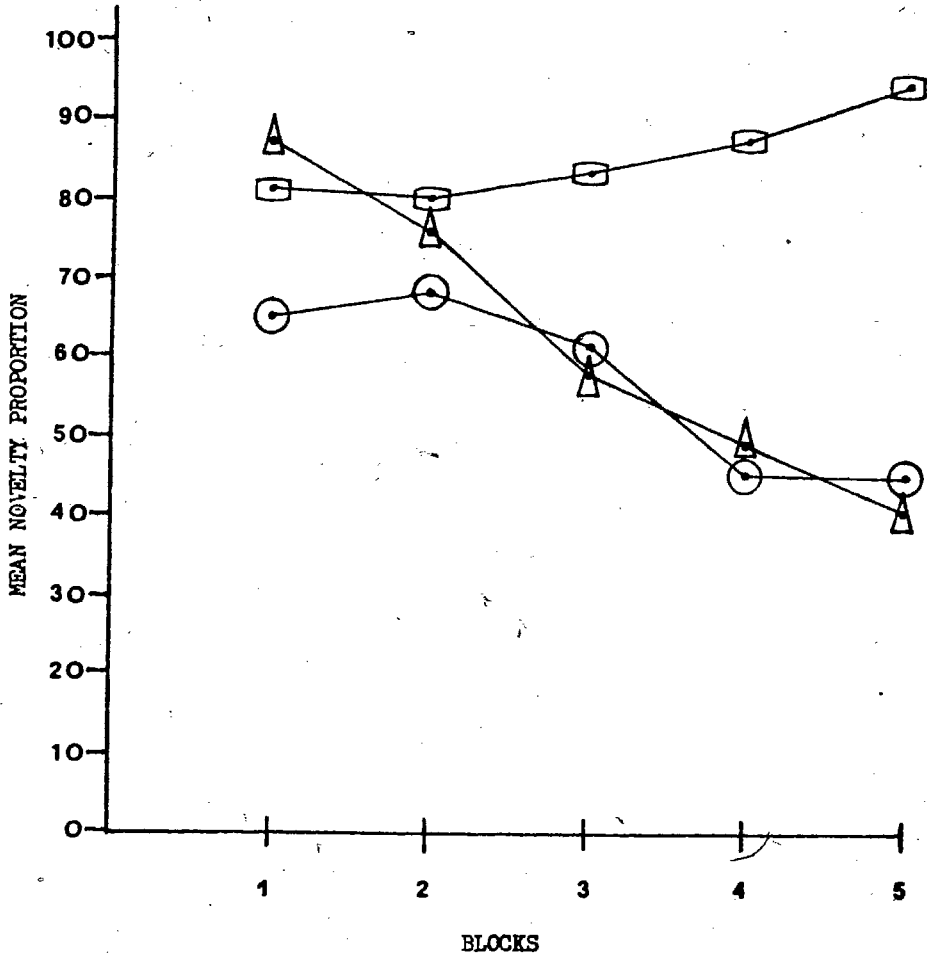


Figure 22  
Groups X blocks interaction.  
( Focused manipulation )

- 8 months
- 12 months simple
- △ 12 months complex





were due to the 12-month-old simple stimulus infants spending a higher proportion of their time with novel toys than either the 8-month-old or the 12-month-old complex stimulus groups.

The absolute analysis of preferences over blocks showed that in general habituated groups in both location conditions preferred toys in the novel array throughout most of the trial (Table 8). Collapsing over location conditions produced novelty preferences for all habituated groups at each block with the exception of block 5 for the 12-month-old complex stimulus group (Table 9). For interrupted infants, however, preferences differed as a function of which groups X location subgroup they belonged to. Interrupted 8-month-old and 12-month-old complex stimulus groups tended to prefer familiar toys throughout the trial when those toys remained in the familiar location. When the familiar toys were in the novel location, the 12-month-old complex stimulus infants showed an initial preference for novel toys at block 1 followed by a preference for familiar toys by block 3 which continued through block 5. Thus, their initial return to the familiar location (which in this condition contained novel toys) precluded an overall preference for familiar toys until block 3 (Table 9). A similar, less dramatic shift from novel to familiar toys by the 8-month-olds resulted in their never showing a statistical preference for either array of toys, although as a whole the interrupted 8-month-olds also preferred the familiar toys by block 3 (Table 9). In contrast to

the complex stimulus groups, the interrupted 12-month-old simple stimulus groups showed no preference for either array until block 5 when those infants in the familiar toy-familiar location condition preferred the novel toys (Table 8) as did the group as a whole (Table 9).

#### IV. DISCUSSION

With relatively few qualifications the two purposes of this study were met. First, Hunter, Ross and Ames' (in press) finding of a familiarity preference in infants older than 2 months was reaffirmed. Second, taken together, the results of this study support the hypothesis that the direction of exploratory preference is jointly determined by amount of previous familiarization, age-related stimulus complexity and response type. Several specific predictions derived from this hypothesis were outlined at the end of Chapter 1. The discussion section will focus on these predictions and their theoretical significance.

In general, infants took longer to habituate to and engaged in more focused manipulation with a complex stimulus than with a simple stimulus. As infants who had habituated to a simple stimulus tended to show their peak response early in the familiarization trial, whereas the peak response of infants who had habituated to a complex stimulus occurred on average much later, the data were consonant with an inverted-U function relating exploration and interstimulus novelty, a function that was dependent upon stimulus complexity.

The habituation data for the 8-month-olds contrasted with

those for the 12-month-olds who had been habituated with a same sized array and were comparable to those found for 12-month-olds who had been habituated with a more complex array. Had only the 8-month-old and 12-month-old simple stimulus groups been included in the study, the results could have been interpreted merely as an age difference in the rate of habituation, with younger infants taking longer to habituate than older infants (cf. Wetherford and Cohen, 1973). Similarly, had the study included only the 12-month-old simple stimulus and 12-month-old complex stimulus groups the results would have suggested only that habituation varies with the complexity of the stimulus (cf. Caron and Caron, 1969; Cohen, Deloache and Rissman, 1975). By including all three groups, the present results offer evidence that these interpretations, while true in a restricted sense, provide only partial understanding of the relation between age, stimulus complexity and habituation. That is, age differences in rate of habituation are isolated when stimulus complexity is held constant over age. As well, habituation varies as a function of stimulus complexity, but this is revealed clearly only for same-aged infants. The present results encompass all three variables, and are consistent with the notion that rate of habituation does vary according to complexity, but that complexity must be defined according to age.

The 8-month-old and 12-month-old simple stimulus groups differed as predicted in habituation rate but did not differ

significantly in total amount of focused manipulation, although the results were in the predicted direction. The lack of significant results may have been due to differences in the diversity of exploratory behavior used by each group. That is, as well as using focused manipulation, the 8-month-olds were probably cleaning information via the mouthing that is characteristic of their age and which, unfortunately, only the observer's memory rather than data can attest to. However, other studies of this age range have also reported a larger amount of oral exploration by younger than by older infants (McCall, 1974; McQuiston and Wachs, 1979). Thus, the 8-month-olds may not have used significantly more focused manipulation than the 12-month-olds simple stimulus groups, but they may have explored more overall.

Both the habituated 8-month-old and the habituated 12-month-old complex stimulus groups subsequently spent more time on visual exploration and focused manipulation of a novel array than did their interrupted counterparts. A similar difference between habituated and interrupted 12-month-old simple stimulus infants for both measures was not as large as for the other two groups. Combined, these results support the prediction that both amount of familiarization and age-related complexity underly the relation between exploration and interstimulus novelty. Several other studies have observed differences in visual novelty response among groups that have

differed with respect to amount of familiarization and the physical complexity of the stimulus familiarized (Caron et al., 1977; Cornell, 1979; Faqan, 1974; Rose, 1980). The present research expanded upon these experiments by pointing out the importance of defining complexity with reference to age. Indeed, this point might be sufficient to explain a discrepancy between Rose's (1980) and Cornell's (1979) studies. Rose (1980) found a stronger novelty response in 6-month-olds than did Cornell (1979) in 5-month-olds when infants in both studies had previously been familiarized to an identical stimulus for the same amount of time. The situation is analogous to the 8-month-old interrupted and 12-month-old simple stimulus interrupted groups in the present study. That is, although the complexity level of the 3-toy-array was physically the same for the two groups, the same brief amount of familiarization produced a stronger novelty response for the 12-month-olds. A more physically complex stimulus (or completed habituation) was required to produce similar results for the two age groups. Thus, had Rose (1980) used a more complex stimulus, or Cornell (1979) a simpler one (or a longer familiarization time to the complex stimulus) the difference between their age groups may not have appeared.

Assuming that both amount of familiarization and age-related complexity determine differences in proportion of time spent with novel stimuli, whether or not those differences

will lead to opposing preferences depends on a third factor: response type. The present research indicates that it is fallacious to attribute the progression from familiarity preference to novelty preference merely to age, when amount of familiarization, age-related complexity and response type are also relevant factors. In both age groups, when focused manipulation was the measure of exploratory behavior and when the stimulus was complex relative to the infants' age, different amounts of familiarization produced a familiarity-novelty progression. In contrast, a progression from no preference following interruption to a novelty preference following habituation was the general result when vision alone was the measure of exploration. As the results were the same for 8-month-olds and 12-month-olds, there is no evidence here to support the idea that a general attraction for what is familiar occurs at an early age and is followed by a general preference for what is novel. Rather, the progression from familiarity preference to novelty preference is present at all ages and represents a process occurring repeatedly as new stimuli are encountered. What do change developmentally are the effective complexity of the stimuli, the amount of familiarization and the form of response necessary to elicit the progression.

These findings both support and expand upon previous research. The vision alone preferences corroborate those reported by Cornell (1979), Faqan (1974) and Rose (1980). The

focused manipulation data reaffirm Hunter et al's (in press) results and extend them by including another age group and by manipulating complexity. Finally, the direct comparison of the two exploration response types may help alleviate many of the potentially contentious differences between those studies.

A discrepancy between the present study and the earlier work on visual exploration concerns the amount of familiarization necessary to produce a visual novelty preference. Using 5- to 6-month-old infants and 2-dimensional stimuli varying in complexity, previous research has found visual novelty preferences following familiarization times ranging from 5 seconds for simple stimuli to 30 seconds for more complex stimuli (Cornell, 1979; Fagan, 1974; Rose, 1980). The interrupted infants in the present study did not show a novelty preference following an average of 102.6 seconds of familiarization. Two methodological differences may have contributed to this difference. First, the arrays of toys used in the present study may have been more complex than the 2-dimensional geometric forms and pictures used in the earlier work. Certainly, 3-dimensional objects contain more of the palpable features suggested to attract infants' attention than do 2-dimensional stimuli. Second, the previous research investigated visual preferences following visual familiarization whereas in the present study testing for visual preferences was preceded by familiarization involving both vision and



manipulation. As other research using both kinds of familiarization procedures has found greater visual novelty preferences following visual familiarization than following visual-manipulatory familiarization (Gottfried, Rose and Bridger, 1978), familiarization procedure may have been the reason for differences between this and earlier studies. Gottfried et al. (1978) explained their results by suggesting that manipulation interferes with visual memory and therefore with visual recognition (as measured by a significant novelty preference). However, Ruff (1980) has suggested, and I agree, that manipulation may enhance object recognition by providing more information about the object's structure. Recognition may take longer because attention may be focused on such properties as smoothness and texture rather than on 2-dimensional features such as color. Perhaps had Gottfried et al. (1978) allowed more time, novelty preferences would have accrued following visual-manipulatory familiarization as well. Thus, the interrupted infants in the present study may not have shown a visual preference even following comparatively long familiarization because their attention was distributed to more and probably different stimulus characteristics than is the attention of infants who are familiarized strictly via the visual mode.

The results of this study are best interpreted in terms of Berlyne's (1960, 1970) optimal level theory of exploration.

According to this theory the amount of exploration elicited by a stimulus is jointly determined by the amount of information in that stimulus and the information processing abilities of the explorer. If the stimulus is complex relative to the explorer, exploration is predicted to follow an inverted-U course with familiarization due to the antagonistic factors, positive-habituation and tedium. Exploration will at first increase as a function of increased attraction for an object that is becoming assimilated (positive-habituation). Once this is accomplished, further familiarization will result in a decrease in exploration due to the repetition of information that has already been learned (tedium). A novel stimulus introduced after exploration has decreased will be preferred, whereas a familiar stimulus will be preferred if the novel stimulus is introduced when exploration is still increasing or at a high level. Exploration of a stimulus that is simple relative to the capacities of the explorer will succumb to the tedium factor relatively quickly and thereby follow a monotonically decreasing course with familiarization. Since exploration of a relatively simple stimulus is always decreasing over time, a novel stimulus introduced at any point during familiarization will receive a greater proportion of total exploration.

The issue of response type as a determinant of exploratory behavior has not been addressed by Berlyne's or any other

optimal level theory. The present study suggests that this factor need be explicitly incorporated into any formula attempting to describe exploratory behavior over age. That is, it appears that with age increasingly complex forms of exploratory behavior are used to seek out and learn about increasingly complex stimuli.

The results with respect to the effect of location on object exploration replicate those reported by Hunter et al. (in press) and seem to show that the tendency to return to a familiar location when faced with insufficient information about other properties of a stimulus is limited to infants older than 8 months of age. This result is not in agreement with a representation-by-action view of object recognition (e.g., Piaget, 1954). By that account 8-month-olds who had been interrupted should have been just as likely if not more so to use the completed action of having previously found the familiar array as as subsequent recognition cue.

An alternative approach, Gibson's (1969) perceptual learning theory, seems more plausible. According to this view, mere exposure to an object leads to learning about the properties of the object (e.g., distinctive features, structural invariants) through the process of differentiation. Perceptual learning through differentiation requires no external guidance or reinforcement; rather, it is seen to be related simply to amount of exposure and to the number of features or invariants

to be differentiated. Further, differentiation is suggested to become more efficient, and therefore perceptual learning more rapid, with age. In the present experiment, all three groups of infants, when given enough time to fully explore the features of the familiar array, were subsequently able to distinguish and accurately find a novel array. When less time was given, the interrupted 12-month-old complex stimulus infants had apparently been able to extract at least one feature of the familiar array, i.e., its location, and used that feature to form a logical search strategy for finding the familiar toys (their overall preference for the familiar array suggests that it was the goal of their search). The interrupted 8-month-olds were also seeking the familiar toys, but were less likely to rely on location as a cue for finding them. It is not certain from the present data, however, that the 8-month-olds were less able to extract location as a feature of the array; instead, they may have been less able to use that feature to provide a search strategy. Their ability to find the familiar array when it was in the familiar location suggests that they were aware of location as a distinguishing feature and, in that situation, were capable of using it in order to find the familiar toys. However, when the familiar toys were moved to the novel location the 8-month-olds' initial choices were essentially random. Apparently, when faced with such ambiguity, the 8-month-olds were less able to use location to form a search strategy and instead relied on a trial

and error strategy of guessing first and adjusting later. Paradoxically, in this experiment, the less advanced strategy resulted in more success. When the familiar toys had been moved to the novel location, trial and error search lead to the interrupted 8-month-olds finding the familiar array 50 percent of the time. On the other hand, the use of a logical search strategy based on location led the 12-month-olds in the familiar toys - familiar location condition to greater initial contact with novel toys. Thus, the search strategy used by the 8-month-olds may have resulted in inflated scores for their initial contact of familiar toys.

As was the case for the interrupted 8-month-olds, the interrupted 12-month-old simple stimulus infants were less prone to use location as a cue for distinguishing between arrays than did the interrupted 12-month-old complex stimulus infants. The suggestion that the 12-month-old simple stimulus group was inferior to the 12-month-old complex stimulus group in their ability to differentiate features and to form logical search strategies would be opposite to the prediction of differentiation theory as well as counter-intuitive since a 3-toy array should have been more fully differentiated than a 5-toy array in the same period of time. A better explanation might be that infants in the 12-month-old simple stimulus group not only had differentiated location as a feature of the familiar array but, because the array was simpler, had been able

to differentiate other distinctive features as well. Thus, they may have been perfectly able to distinguish and find the array they wished to explore and their initial choice data merely reflected variation within the group as to which array was being sought. The overall lack of preference for either the familiar or the novel array suggests that this may be true.

The explanation presented above is only tentative. However, regardless of how the location results are explained, they help provide some of the most compelling evidence that infants are motivated to complete unfinished exploration before moving on to explore new stimuli. That is, whatever the reason why some infants interrupted with a complex array initially approached and contacted the novel toys, there is no obvious reason for them to have left those toys other than to resume exploration of the familiar array.

### Conclusion

The research presented in this thesis has demonstrated that infants do not always prefer familiar stimuli at one age and novel stimuli at a later age, but that under some circumstances they will show a progression from familiarity preference to novelty preference at any age. This finding suggests that infants explore in an orderly manner with the purpose of learning about the objects in their environment. They do not haphazardly look at and manipulate objects but do so

successively as the properties of each become assimilated. If this process is interrupted they will return to resume exploration and complete learning before moving on to new things.

## V. Footnotes

<sup>1</sup>This discussion is based on and much of it is the same as that which appears in a similar section of my M.A. thesis (Hunter, 1978).

<sup>2</sup>The  $\ln$  transformation in effect transformed the data from an interval scale to a ratio scale of measurement which was preserved by the retransformed standard deviations. Since ratio scales are multiplicative rather than additive  $\bar{X} \pm S.D.$  becomes  $\bar{X}(S.D.)^{\pm 1}$ . Notice also, that the retransformed means also have ratio scale properties such that a retransformed mean of value 150 seconds would be interpreted not merely as 100 seconds greater than a retransformed mean equal 50 seconds, but as three times greater.



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## VII. Appendix A - Reliability

Investigators have typically used either correlation coefficients or average percent agreement indices (but not both) in order to determine the extent to which the results of their studies are reliable. Consider the 2 X 2 table presented below. It represents a matrix of judgements obtained from two independent observers on a single subject.

		OBSERVER 2		
		Behavior	No Behavior	
OBSERVER 1	Behavior	a	b	e
	No Behavior	c	d	f
		g	h	

The correlation technique involves using quantities e and g for each subject to compute a Pearson product moment correlation coefficient. Average percent agreement is derived by computing  $(a+d)/(a+b+c+d)$  and averaging over subjects.

Two criticisms can be made concerning the use of these indices. First, although they are often used interchangeably (and interpreted in the same way) they can be shown to provide different kinds of information to the extent that one index might show a result that contradicts the other. Second, average

percent agreement can be shown, at best, to be only a primitive approach to determining reliability.

The first point can be easily demonstrated. In the table presented below, percent agreement is equal to 0.0 while the amount of behavior reported by each observer is identical. Such a pattern would be implied by two observers looking at two unrelated phenomena that occur at the same base rate. If this pattern was consistent over subjects the Pearson correlation coefficient would suggest high reliability even though percent agreement is low.

		OBSERVER 2		
		Behavior	No Behavior	
OBSERVER 1	Behavior	0	50	50
	No Behavior	50	0	50
		50	50	

This situation points up the differential information provided by the two measures. On the one hand, the correlation coefficient indicates the extent to which there is an association between the means of two observers regardless of the association between observers within subjects. Percent agreement, on the other hand, attempts to index only the degree of observer association within subjects. As shown in the above example, a particular value on one measure does not mean that the other will perforce equal a similar value. Indeed, only if

agreement is 100 percent can one be certain that the correlation coefficient will also be high (1.00). Thus it is imperative that reliability be reported both in terms of a between subjects measure of association (correlation) and in terms of a within subjects measure of association.

Unfortunately, percent agreement is relatively insensitive for its intended purpose and again an example will help show why. Consider a situation in which agreement is reported to equal 82 percent. This value would be consistent with both of the table presented below.

(a)

OBSERVER 2

		Behavior	No Behavior	
OBSERVER 1	Behavior	41	9	50
	No Behavior	9	41	50
		50	50	

(b)

OBSERVER 2

		Behavior	No Behavior	
OBSERVER 1	Behavior	81	9	90
	No Behavior	9	81	90
		90	90	

It requires relatively little in the way of sophistication to appreciate the inadequacy of this measure. By reporting only a single percentage based on the total of the main diagonal cells no information concerning the distribution of agreement over categories is possible. In table (a) agreement is equal and high both for behavior and for no behavior. In table (b), however, agreement is high for behavior, but low for no behavior. Since the values in the a and d cells could be interchanged and still show the same percent agreement, it is possible that what appears to be high reliability may merely reflect the fact that the behavior of interest is rare and that its non-occurrence is easy to judge. Further, as was the case with the example presented earlier, the values in table (b) would be implied by both observers looking at different unrelated phenomena that occur at the same base rate. However, in contrast to the previous example the base rate is high for both phenomena and therefore the agreement appears to be high even though it is simply the amount of agreement that would be expected by chance.

A better measure of agreement, kappa, has been proposed by Cohen (1960), which is the proportion of agreement after chance agreement has been removed. Kappa is computed by subtracting from the proportion of judgments in which the observers agreed (the sum of the main diagonal) the proportion of agreements to be expected by chance (the sum of the products of the main diagonal marginal proportions) and dividing this quantity by one

minus the proportion to be expected by chance. For the examples presented above, kappa would be derived as follows:

EXAMPLE 1.

$$\begin{aligned} \text{proportion of observed agreement} &= 0.0 + 0.0 = 0.0 \\ \text{proportion expected by chance} &= 0.25 + 0.25 = 0.50 \\ k &= 0.0 - 0.50 \\ &= 1.0 - 0.50 \\ &= -1.0 \end{aligned}$$

EXAMPLE 2a.

$$\begin{aligned} \text{proportion of observed agreement} &= 0.41 + 0.41 = 0.82 \\ \text{proportion expected by chance} &= 0.25 + 0.25 = 0.50 \\ k &= 0.82 - 0.50 \\ &= 1.0 - 0.50 \\ &= 0.64 \end{aligned}$$

EXAMPLE 2b.

$$\begin{aligned} \text{proportion of observed agreement} &= 0.81 + 0.01 = 0.82 \\ \text{proportion expected by chance} &= 0.81 + 0.01 = 0.82 \\ k &= 0.82 - 0.82 \\ &= 1.0 - 0.82 \\ &= 0.0 \end{aligned}$$

With  $k = -1.00$ , we see that there is greater disagreement than would be expected by chance. Examples 2a and 2b are more interesting because reliability as measured by percent agreement was equal for both. Kappa suggests that attributing equal reliability is fallacious. In one case (2a) 64 percent of the



joint judgements) are agreements (with chance excluded). In the other (2b), however, the joint judgements are precisely the number that would be expected by chance.

In sum, it has been argued that measures both of between subject reliability and within subject reliability are important when reporting behavioral research. In the present study, two observers made judgements concerning first-location-entered, particular toy being touched and focused manipulation for 52 infants (thirteen 8-month-olds, sixteen 12-month-olds simple stimulus and twenty-three 12-month-olds complex stimulus). Visual exploration without concurrent manipulation during the first 20 seconds of the test trial was recorded by two independent observers for 24 infants (eight in each group).

There was no disagreement (and therefore perfect correlation) both for first location entered and for particular toy touched. Correlation coefficients and individual kappas were computed on the first 20 seconds of vision alone during the test trial. For the 8-month-olds  $r = .98$  and the mean  $k$  value was  $.91$  (S.D. =  $.10$ ). For the 12-month-olds simple stimulus  $r = .96$  and the mean  $k$  was  $.87$  (S.D. =  $.12$ ). For the 12-month-olds complex stimulus  $r = .96$  and the mean  $k$  was  $.89$  (S.D. =  $.09$ ).

On focused manipulation, kappa was computed for each infants in each group both for the familiarization and the test trials. As well, product moment correlations were derived for each group X trial subgroup. For illustrative purposes the data

and the computations are presented below.

From the results presented in this appendix it is apparent that all reported findings and all behaviors on which those findings were based were reliable.

8-month-olds	Familiarization Trial				Test Trial			
	O <sub>1</sub>	O <sub>2</sub>	O <sub>1</sub> O <sub>2</sub>	k	O <sub>1</sub>	O <sub>2</sub>	O <sub>1</sub> O <sub>2</sub>	k
1.	.20	.21	.20	.98	.49	.49	.49	1.00
2.	.47	.47	.47	1.00	.47	.47	.47	1.00
3.	.68	.67	.66	.93	.35	.38	.32	.83
4.	.27	.28	.27	.98	.45	.45	.45	1.00
5.	.67	.67	.67	1.00	.77	.77	.77	1.00
6.	.48	.44	.41	.81	.44	.45	.39	.76
7.	.24	.19	.18	.84	.11	.11	.11	1.00
8.	.56	.53	.52	.89	.81	.77	.75	.77
9.	.58	.58	.54	.84	.51	.49	.48	.94
10.	.55	.57	.54	.92	.16	.17	.15	.92
11.	.37	.41	.34	.79	.39	.40	.32	.71
12.	.53	.51	.49	.87	.69	.65	.63	.82
13.	.35	.34	.34	.98	.38	.46	.37	.82
	mean k = .91				mean k = .89			
	S.D. = .08				S.D. = .11			
	r = .98				r = .99			

12-month-olds simple stimulus

1.	.32	.30	.29	.89	.40	.33	.32	.83
2.	.58	.50	.44	.61	.31	.28	.26	.85
3.	.50	.56	.49	.83	.37	.39	.36	.93
4.	.32	.32	.32	1.00	.15	.15	.15	1.00
5.	.42	.42	.40	.93	.67	.61	.58	.73
6.	.50	.47	.45	.86	.79	.76	.75	.86
7.	.56	.62	.55	.84	.44	.46	.41	.84
8.	.50	.49	.46	.86	.31	.29	.27	.86
9.	.43	.43	.43	1.00	.49	.49	.49	1.00
10.	.27	.25	.21	.74	.45	.43	.39	.80

12-month-olds simple stimulus - cont'd

	Familiarization Trial				Test Trial			
	O <sub>1</sub>	O <sub>2</sub>	O <sub>1</sub> O <sub>2</sub>	k	O <sub>1</sub>	O <sub>2</sub>	O <sub>1</sub> O <sub>2</sub>	k
11.	.46	.45	.45	.98	.66	.65	.65	.98
12.	.34	.34	.34	1.00	.31	.31	.31	1.00
13.	.27	.27	.27	1.00	.40	.40	.40	1.00
14.	.35	.37	.35	.97	.44	.44	.44	1.00
15.	.63	.60	.60	.94	.58	.58	.54	.84
16.	.55	.56	.55	.98	.43	.43	.41	.97

mean k = .90  
S.D. = .11  
r = .98

mean k = .91  
S.D. = .09  
r = .98

12-month-old complex stimulus

1.	.32	.38	.29	.74	.51	.56	.48	.80
2.	.35	.33	.30	.82	.60	.56	.48	.80
3.	.41	.41	.35	.75	.50	.48	.46	.88
4.	.65	.65	.65	1.00	.25	.25	.25	1.00
5.	.51	.52	.45	.74	.60	.56	.51	.75
6.	.45	.46	.44	.94	.32	.31	.30	.93
7.	.48	.49	.43	.78	.63	.59	.58	.87
8.	.28	.28	.26	.95	.30	.29	.26	.83
9.	.58	.59	.54	.81	.59	.60	.53	.73
10.	.44	.45	.44	.98	.59	.59	.59	1.00
11.	.28	.28	.28	1.00	.46	.46	.46	1.00
12.	.31	.32	.30	.93	.43	.43	.40	.88
13.	.47	.46	.42	.84	.41	.47	.49	.80
14.	.47	.44	.42	.84	.40	.44	.35	.71
15.	.18	.18	.17	.94	.52	.48	.46	.84
16.	.50	.52	.50	.96	.70	.67	.63	.75
17.	.45	.43	.39	.80	.61	.64	.55	.68

12-month-olds complex stimulus - cont'd

	Familiarization Trial				Test Trial			
	$O_1$	$O_2$	$O_1O_2$	k	$O_1$	$O_2$	$O_1O_2$	k
18.	.45	.45	.45	1.00	.62	.63	.62	.98
19.	.49	.48	.48	.98	.44	.44	.44	1.00
20.	.19	.19	.17	.90	.20	.21	.16	.72
21.	.22	.22	.22	1.00	.15	.15	.15	1.00
22.	.60	.60	.60	1.00	.66	.63	.60	.80
23.	.46	.47	.45	.94	.24	.23	.23	.98
	mean k = .90				mean k = .87			
	S.D. = .09				S.D. = .08			
	r = .99				r = .99			

Note:  $O_1$  = the proportion of behavior reported by observer 1

$O_2$  = the proportion of behavior reported by observer 2

$O_1O_2$  = the proportion of behavior agreed upon by both observers

Reference

Cohen, J. A coefficient of agreement for nominal scales. Educational

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