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Perceived structure and the maintenance of attention.

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PERCEIVED STRUCTURE AND THE MAINTENANCE OF ATTENTION

A Dissertation Presented

By

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DEDICATION

With love and appreciation

to

Anthony D. Pugzles and Elizabeth F. Pugzles

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ABSTRACT

Perceived Structure and the Maintenance of Attention

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When individuals are presented with a task situation for which they must use complex, sequentially available information, they must construct organizations for this information in order to perform the task effectively. For example, organizing incoming information allows the individual to remember more information, and to predict and prepare for information yet to come. The hypothesis tested in the present study is that such organizations have an impact on an individual's ability to maintain attention to a task and resist distractions in the environment. Specifically, it was hypothesized that (1) people can attain complex, hierarchically organized structures for incoming information; (2) that the boundaries between the units highest in the hierarchy constitute major breaks in the processing and integration of information; and (3) that these major "breakpoints" are times when people are especially vulnerable to distraction.

In the experiment, subjects were trained to perceive particular, defined structures in sequences of stimuli. After training, they performed a task in the context of a video game requiring speeded predictions or classifications of stimulus events. Within the sequences which had been learned, information irrelevant to the task was sometimes displayed.

Overall, subjects' response times in the classification/prediction task indicated the psychological reality of the structures for them as they produced responses more slowly when near a high level unit boundary. They were also affected by distraction, slowing performance significantly when distractions were present. However, the major hypothesis was not confirmed: Distraction did not affect performance differentially for higher level units. This null finding is made compelling by the tremendous statistical power of the analysis.

The results were interpreted in the light of possible alternative hypotheses; notably, that distraction affects performance in a strictly momentary way, unrelated to sequences of information that the individual processes. In addition, a major limitation to the present test of the hypothesis is discussed, and a revised test of the hypothesis is proposed. The potential relevance of the hypoth-

esis to theories of the development of attention is described.

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CHAPTER I

INTRODUCTION

Much of human behavior is goal-directed, and much of the information necessary to meet goals becomes available sequentially. In order to effectively use such sequentially presented information, we must organize and integrate successive pieces of information as they relate to our goals. Possibly in interaction with the processes through which we integrate information, we must direct our attention over time, in order to continually have relevant information available. This dissertation examines a specific interaction between perceived organizations of information and the ability to maintain attention to and resist distraction from a task using sequential stimuli. A theoretical viewpoint is defined which predicts differences in the degree to which irrelevant stimuli interfere with performance as a function of level of organization within structures for sequentially presented, task-relevant stimuli. This viewpoint is developed in the context of a general perspective on perception and information processing, and of research relating delineated structures to the perception, learning, and understanding of sequential stimuli. The experiment reported here is an initial examination of predictions for adult performance.

Theoretical Development and Literature Review

Assume a situation where an individual must engage in goal-directed behavior. In order to meet the requirements of the situation, the individual must obtain relevant information, make decisions on the basis of this information, and respond overtly according to these decisions.

General perspective. The theoretical notions developed here are rooted in a general perspective on perception and information processing. The process of perceiving and acting on information is seen as an interaction involving structured, generalized expectancies built from past experience, specific expectancies concerning immediately relevant input, and the stimulus input itself. Due to the interactions between expectancies and input, the information that is obtained will reflect the impact of the structured expectancies, but obtaining that information will modify these expectancies, and so on in a continuous cycle of interactions as long as the task and input continue. As performance of the hypothetical task continues, the individual's efficiency may increase: the structure held by the individual may more and more closely approach an "ideal" structure of the information as it relates to task demands. Such a structure would presumably be highly organized, integrating as much information as is needed to

have an adequate view of what further information is necessary to meet task demands, and to allow anticipations of information likely to be available.

If a task is complex, it may be particularly important to develop an organization adequate to its demands, else performance would be expected to suffer. Given a complex task, the individual may have to build a hierarchical structure of task-relevant information, in which discrete pieces of information are integrated into higher order components. When appropriate, such a structure could reduce the individual's memory load for past events and help to build anticipations of future higher order components.

The notion that people develop structures which affect their behavior and the way they obtain information from the world is hardly unknown. The idea runs through the work of Piaget and Bruner in developmental psychology, appears in theorizing in cognitive psychology (e.g., Hochberg, 1970; Kahneman, 1973; Neisser, 1967; 1976; 1979; Norman & Bobrow, 1976; Pick, 1979; Schank & Abelson, 1977; Posner, 1978), and is the core of several theoretical syntheses of physiological psychology and skilled behavior (Bindra, 1976; 1978; Hebb, 1949; Lashley, 1951). Several examples are discussed below.

Lashley (1951), Hebb (1949), and Bindra (1976; 1978), for example, have all addressed questions concerning the

mechanisms for the serial organization of behavior, particularly purposeful, goal-directed, "intelligent" behavior. Lashley (1951), in a paper considred classic, proposed the idea of a schema of order. The schema of order is a generalized pattern which directs the order of production of individual acts. Such a schema develops through experience, and can continue to be modified with experience. Lashley suggested that these generalized patterns are hierarchically organized, and provided a number of examples from the perception and production of language, music, and other skills to illustrate the point. The generalized schemata are not necessarily invested with highly specific content, however. Lashley represented the physiological equivalent of the schema of order as continuing, organized excitation in the neural system. Thus, when particular content does enter the system as stimulus input, it produces not merely a response to its presence, but begins an interaction with an already dynamic system.

Hebb (1949) and Bindra (1976; 1978) were also concerned with accounting for the organization of skilled behavior. They described similar hierarchically organized neural systems for the perception of information and the direction of behavior. In both systems, the organizational structures develop with experience. The structures are not actual physical structures, but might be thought of as

likely organizations of neural excitations in a serially constructed perceptual process. Both systems include several levels of organization, in which the higher levels of organization are increasingly involved in processes of goal anticipation and need less sensory support. Thus, the higher level organizations in these systems enable increasingly efficient progress between sequential responses necessary in a goal-directed situation. Bindra (1976) introduced an additional aspect: the momentary determining set. A momentary determining set is a cluster of upper level organizations ("contingency organizations") which are excited by the present situation. A momentary determining set, then, represents the operation of high level, directive organizations even in restricted contexts.

The idea of organized structures which direct information seeking and which are continually modified by the information obtained is the central concept in Neisser's (1976; 1979) recent writings on perceptual processing. Neisser (1976) outlines the perceptual cycle, in which perception of an object modifies internal schemata, which then direct exploration of stimuli, thus sampling additional information to continue the cycle. Neisser's schema is a conceptualization of the internal structure which functions both to pick up information and to use it to direct further perceptions. The schema can be at least

in part a function of specific task demands. It is due to the activity of the schemata that anticipations are formed within a perceptual cycle, while unanticipated events can initiate a new perceptual cycle. The schemata develop as a function of experience, and are also said to attain an embedded organization, where a larger schema directs the activities of the schemata embedded within it. Neisser has reported research (1976; 1979; Neisser & Dube, Note 1) consistent with these notions (i.e., that people can construct anticipations based on the kinds of stimulus information available which allow for efficient performance of a continuous task). It should be noted, however, that these ideas would be very difficult to disconfirm. Failure to construct appropriate sequences of anticipations could always be attributed to lack of the schemata or precursors to the schemata required to initiate the appropriate perceptual cycle. This, of course, is a problem with this general type of perspective, since schemata are always seen as complex and ever-changing.

Nevertheless, similar notions have been incorporated into other viewpoints and theories concerning complex cognition. They often appear in explanations of the facilitative effects of perceptual set (Day & Stone, 1980; Hochberg, 1970; Norman & Bobrow, 1976). Hochberg, for example, has suggested that perceptual organization results

from the ways in which sets of anticipations come to be structured, and that testing such sets of anticipations is the basis for focal conscious experience and selective attention. Pick (1979) applied related ideas to a conceptualization of how people learn to perceive melodies. In her view, structures for short, simple musical events are developed, then progressively become embedded in more complex, higher order structures. The latter, in turn, direct the integrated perception of the components. There has also been work specifying goal-directed behavior as the consequence of the operation of hierarchically structured scripts and plans (e.g., Graesser, 1978; Miller, Galanter, & Pribram, 1960; Schank & Abelson, 1977), which are representations of relevant procedures, information, or choices which are used and monitored in the progress toward a goal.

Defining structural units. The preceding section demonstrated that this general perspective on information processing is at least prevalent and perhaps plausible. It is obviously difficult, however, to determine what schemata are active in an individual's head, and how these are modified and organized. But, if a sequence of information can be said to have an objective structure, an individual's response to the situation may be indicative of

the organization directing task-related perceptual activity. An example comes from Darren Newtson's work (1976a; 1976b) investigating how people perceive the ongoing behavior of other individuals. In a typical procedure, adult subjects watched films in which an actor performed simple action sequences, often involving considerable repetition. The subjects were to mark the films into naturally occurring behavior sequences, noting when one action seemed to end and another to begin. Newtson found that there were some time periods in which many subjects placed a mark; these intervals were termed "breakpoints". Newtson determined that breakpoints seemed to be intervals high in information value (e.g., subjects could detect deletions of breakpoints better than they could detect deletions of nonbreakpoints from a film, and could derive more meaning from a slide sequence consisting of breakpoints than one made up of nonbreakpoints (Newtson, 1976c)). It was also found that the points subjects marked could be reliably changed through instructions. For example, subjects could make the "largest possible" and the "smallest possible" breakpoints. In addition, the smallest units were generally embedded within the larger units that were marked. One could speculate that the structure of these breakpoints might be representative of the organization of the schemata directing perceptual activity. It might seem,

then, that the larger schemata are taking shape during ongoing perception and are serving to integrate some of the individual components that are perceived.

Another area of research demonstrating relationships between behavior and specified structures for sequentially presented stimulus material is the investigation of people's representation of text. In this research, formal analyses of text structure have been shown to predict the kinds of information likely to be recalled from the text. Some analyses have emphasized the propositional structure of the text, defining a text in terms of simple propositions connected by a network of interrelationships. Such a network would generally be assumed to be an hierarchically organized structure in which propositions at a higher level of the structure integrate and summarize propositions at lower levels. The structure can be defined more or less objectively, although there is a subjective factor in the assignment of integrations of propositions at higher levels. In addition, however, it may be hypothesized that as the individual is presented with the material, a structure matching the ideal structure is built from the simple propositions. Evidence favoring this hypothesis includes the finding that information high in a given structure is rated more important (Shebilske, 1979) and recalled better (Johnson, 1970; Kintsch, Kozminsky, Streby, McKoon, &

Keenan, 1975; Meyer, 1975; Shebilske, 1979; Thorndyke, 1977) than information low in the structure.

A related approach works from the "top down" rather than from the "bottom up", emphasizing the contribution of generalized, hierarchically organized story structures (schemata) to the representation of the story obtained (e.g., Mandler & Johnson, 1977; Thorndyke, 1977). For example, a story might first be divided into a setting and a plot. The setting might be further divided into information about characters, time, and place. The plot might also be subdivided into "episodes" (e.g., beginning events, development of events, outcome and ending), which can then be further divided into possible components of these episodes. This approach, then, concentrates on the way this type of general structure helps to organize retention. Although the approach is somewhat subjective and is restricted to relatively stereotyped stories, there is evidence that this type of structure plays a role in story representation. For example, stories are rated as more comprehensible (Thorndyke, 1977) and are better recalled (Bower, Black, & Turner, 1979; Kintsch & Greene, 1978; Mandler, 1978) the more they correspond to a conventional story structure. Recall is also better for stories whose subdivisions are presented in accord with a conventional order of schema subdivisions (Bower, et.al., 1979; Mandler,

1978).

Overall, then, despite possible problems in the definitions of structural components and their generality, the research on text representation indicates that subjects appear to integrate information in a fashion appropriate to the hierarchically organized structure of the text. It also indicates that high level components of a structure (which include story-specific material and generalized story components) exert an important organizing influence on representation of the material.

Another body of research relating the structure inherent in sequential stimuli to people's perceptions and performance is that focused specifically on learning sequential patterns of simple stimuli. Typically, subjects are required to predict which of a specified set of events will be presented next. When the sequences of stimuli are predictable (i.e., the sequence has a particular "period" which regularly repeats), the organization of stimuli within the repeating period is important in determining the ease of learning a sequence and the locations producing the greatest or the fewest number of errors. For example, in one group of experiments (Gottwald and Garner, 1967; Royer, 1967; Royer & Garner, 1966), subjects either predicted sequences of binary events (Garner & Gottwald, 1967) or reproduced sequences of binary events as they occurred

(Royer, 1967; Royer & Garner, 1966). In the prediction task, the period of the sequence was five events; for the production task, eight events. Subjects had to keep pace with the rate of event presentation (stimuli on, then off two seconds in the prediction task; two per second (Royer & Garner, 1966) or accelerating from one per second until the maximum rate a subject could maintain was attained (Royer, 1967) in the production task). Thus, in both tasks subjects needed to learn the sequences well in order to consistently respond correctly, since the rates of presentation in the second task were too rapid for them to otherwise keep pace. In some conditions, subjects could delay responding until they felt they knew the sequence. When the ease of learning different patterns and the locations within the patterns where subjects began responding were examined, it was evident that runs of a particular event and single alternations of events were organizers for the subjects. Their presence in a repeating period facilitated learning and allowed for faster maximum response rates. When subjects chose their starting point for responding, they generally began at the boundaries of these kinds of organizers (e.g., rarely within a run of the same event). If the period for a sequence was composed of a group of short runs, learning was facilitated if the period could be organized into a pattern within a pattern

(e.g., 01110111).

Other investigators have extended results such as these and have defined structures which reside in stimuli and which presumably are attained by subjects through learning. A number of languages for sequential structures have been defined, and predictions made about subjects' perceptions and learning of the sequences. Some of these grammatical systems have been related to subjects' judgments of the complexity of sequences (Leeuwenberg, 1969; Payne, 1966; Vitz and Todd, 1967; 1969); others directly to subjects' learning of the sequences (Restle, 1967; 1970; Restle & Brown, 1970; Simon & Kotovsky, 1963). All the systems predict behavior to some degree, although generally not perfectly. Simon (1972) pointed out, however, that all the theoretical systems relating behavior to sequences are variants on a theme, and research to find the "right" system would be fruitless. The variations between the systems are often due to differences in the kinds of stimulus materials and relations comprising the sequences (e.g., letters, musical notes, digits). Moreover, there is a great deal of agreement among the representations of patterned sequences. Some representation of the operations "same" (repeat an event) and "next" (go to the next event in the relevant relation) are included in most systems. The systems all stress the

importance of moving from individual elements to successively higher levels of organization in a sequence, frequently incorporating hierarchical representations for defining entire sequences. The levels of organization have an important role in learning. The highest levels are the most difficult to master (Restle, 1970; Simon & Kostovsky, 1963), but also serve an organizing and memory-load-reducing function which can facilitate mastery of sequences comprising numerous lower level units (Restle & Brown, 1970; Simon & Kostovsky, 1963).

As an illustrative example and because this system was adapted for the purposes of the present experiment, Restle's (1970; Restle & Brown, 1970) system will be defined in somewhat more detail, and the ways in which it relates to sequence learning behavior discussed. The possible stimuli are six lights (Restle, 1970) or six musical notes (Restle & Brown, 1970). Four operations are defined: repetition of events (e.g., R(1 2) = 1 2 1 2); transposition of events (e.g., T(1 2) = 1 2 2 3); mirror image of an event (e.g., based on six notes, M(1 2) = 1 2 6 5); and expansion of event intervals (e.g., E(1 2) = 1 2 1 3). These operations can be nested, producing hierarchically organized sequences. The following is a relatively complex example:

E(M(T(R(T(1))))) =

(1 2) (1 2)

(2 3) (2 3)

(6 5) (6 5)

(5 4) (5 4)

(1 3) (1 3)

(2 4) (2 4)

(6 4) (6 4)

(5 3) (5 3)

Obviously, this system includes the typical characteristics described by Simon: "same" and "next" relations (as well as elaborations of "next" relations) are central, and the system lends itself to the formation of complex, hierarchically defined sequences.

Restle (1970; Restle & Brown, 1970) found that patterns of learning regular, hierarchically-defined sequences closely reflected the defining structures. Error data indicated that locations of highest difficulty immediately followed a high level break in the structure, and that errors in learning decreased with level in the structure. If learning of hierarchically defined sequences was compared with learning of sequences composed of the same subsequences

(e.g., segments in the example structure at the (1 2 1 2) level) but rearranged, the hierarchically organized were learned more quickly. (Subjects do, however, evidence learning of some of the lower level components which remain intact.) If sequences had occasional deviations from a regular structure, learning of the pattern was affected, but only seriously if the deviations occurred in early portions of the structure. Restle interpreted all these results as indicating that cognitive structures which fit these sequence structures arise during serial pattern learning. These structures are presumably built from the "bottom up" for every sequence; in fact, no evidence for "top down" transfer of structures was found. Nevertheless, as these structures take shape, the higher order levels help to reduce memory load and facilitate anticipation of subsequent units of stimulus information.

The research reported in this section has demonstrated that stimulus-based and generalized structures can reliably be defined, and that people apparently employ these in perceiving, learning, understanding, and responding to sequentially presented information. The hierarchical nature of these structures has an important role: high levels can be difficult to attain, but when mastered they carry a good deal of information and facilitate integra-

tion of the information they subsume. Royer (1967) commented, for example, "A point in the sequence where a transition from one unit to another occurs constitutes a juncture or point of articulation around which to organize the sequence into a pattern" (p. 201). The points between high level units, in particular, are seen as times to monitor the ongoing organization and judge how far ahead information and likely responses can be anticipated (Graesser, 1978; Kahneman, 1973; Miller, Galanter, & Pribram, 1960; Schank & Abelson, 1977). Based on these interpretations, in the next section a relationship between such structures and the ability to maintain attention to a task will be hypothesized.

Hypothesis of the relationship between attention and the structure of information in a stimulus sequence. From the evidence discussed thus far, it appears that people both construct structures up to higher levels of units of information, and employ high level units to integrate information and direct further information pickup. The higher the level in the structure, the more that a point between units represents a kind of "stop and regroup" point. While building a structure, people may be more apt to pause and evaluate information at such times. When a structure is mastered, these points may represent

times when performance is more apt to be monitored and decisions made about what type of information is likely to follow (Kahneman, 1973). When at the top of a structure, they may even indicate that no further integration is possible, and that it is time to await information which will initiate a new structure.

The principal hypothesis tested in the present experiment is that an individual's attention to an ongoing task is most vulnerable to distraction at the breakpoints between the highest level units that the individual perceives in the structure. This prediction stems from the idea that these breaks between units will be breaks in processing as well, times when an individual is more likely to be open to irrelevant as well as task-relevant information. On the other hand, to the extent that the individual perceives the complete structure, low level unit boundaries are more likely to be integrated within higher order components of the structure. The higher order units may facilitate anticipation of the information contained within them, making the lower order unit boundaries less likely to be functional "stops" in processing. If a number of events exist within the lowest level of the structure, the effect of distraction on task performance will be least at such "within unit" times.

Because to my knowledge no hypothesis relating attention to the perceived structure of sequential information has been explicitly proposed in a published work, there is little evidence favoring or contradicting this hypothesis. There is, however, a small amount of work suggesting that perceived units play a role in determining attention to task-relevant events and responses to irrelevant events.

Several studies indicate that stimuli or stimulus sequences perceived as coherent units are likely to resist interruption from other events. Fodor & Bever (1965), for example, demonstrated that clicks accompanying the auditory presentation of sentences tended to be perceived not at their actual positions, but displaced towards major linguistic boundaries in the sentences. (Part of the subjects' task was to notice these clicks, so they were not actually irrelevant.) Broadbent (1977), suggested that global analysis of information can allow information to be packaged into "segments", which can then help to direct further detailed stimulus analysis. He presented evidence indicating that well-integrated segments are less likely to permit outside interference. Neisser (1976; 1979; Neisser & Dube, Note 1) presented findings showing that a stimulus outside of a well-integrated set of anticipations is unlikely to affect performance of a task structured around these anticipations. In one study

(Neisser & Dube, Note 1), for example, subjects monitored a filmed sequence of a ball-toss game which included active dark-shirted and light-shirted players. The subjects' task was to make a response when a ball was passed from one dark-shirted player to another, but to ignore another ball game among the light-shirted players. (It had been found in other studies that accuracy of detection was little affected by the presence of the light-shirted players.) During the middle of the film a woman carrying an umbrella strolled across the scene (taking about four seconds to do so). Under normal conditions, not only was there no effect of this event on accuracy, but subjects generally were surprised when told of the woman's presence. Neisser & Dube's interpretation was in part that the woman had nothing to do with the set of anticipations constructed through schemata, and so did not precipitate a break in the perceptual cycle. Similar results were obtained in variations of this procedure, although subjects were more apt to notice an unexpected person who was more active (dancing) and remained in view for a longer period of time.

Other findings demonstrate disruptive effects resulting from forcing an unexpected or potentially interfering event <u>into</u> the unit structure to which people are to attend. For example, Newtson (1973) showed adults

a filmed sequence of an actor constructing a model of a molecule according to a set of eleven instructions. The subjects were to mark the sequence into naturally occurring action sequences. For some of the subjects, an unexpected event was inserted into the construction process (e.g., the actor removed a sock and a shoe and rolled up his pant leg). After the unexpected event occurred, subjects marked the sequence into smaller (more frequently occurring) units than if there had been no unexpected event. In this case, the unexpected event could be considered integral with the ongoing sequence of events being evaluated by the subjects. It may, then, have broken into the structures developed by the subjects, causing them to perceive subsequent events as pieces of a lower order unit structure.

The prefix and suffix effects summarized by Kahneman (1973) also illustrate the effect of incorporating irrelevant material within an integrated unit. The prefix effect refers to the impairment of memory for an auditorily or visually presented string of relevant digits when an irrelevant digit is presented at the beginning of the list. The suffix effect is similar, but occurs when the irrelevant digit is presented at the end of the list. In both cases, subjects know in advance that the particular item may be ignored; nevertheless, its presence

interferes with memory for the relevant digits. Kahneman notes, however, that the effect can be reduced or eliminated if the interfering item is isolated or somehow incorporated into its own perceptual unit, as opposed to being incorporated into the unit comprising the relevant digits. Although these findings and the Newtson results have a limited bearing on the present hypothesis, they do indicate that perceived units of information appear to demand attention to that within their boundaries.

The relationship of this hypothesis to other accounts of interference due to irrelevant stimuli might be considered. To a great extent, it is independent of many such explanations. For example, the present hypothesis does not explicitly deal with differences in effects which accompany variations in the relationship between relevant and irrelevant stimuli (e.g., Garner's (1974; 1970; 1976; 1978) distinction between the effects of "integral" and "separable" stimulus dimensions). Nor does it explicitly address variations in effects owing to an irrelevant stimulus being able to automatically elicit attention (e.g., Jensen & Rohwer, 1966; Lorch, Anderson, & Well, Note 2; Shiffrin & Schneider, 1977; Stroop, 1935). However, it can build on these factors, adding the additional component that the organization which a person builds and uses in an ongoing task situation is an impor-

tant factor in determining the patterns of interference which may result.

Of any issue considered in theories of attention, the present hypothesis relates most closely to the issue of automatic processing in skilled performance. A frequently cited aspect in the development of automatic processing is the effort-demanding process of integrating small units of stimulus information into larger units of schemata (Blumenthal, 1977; Bruner, 1973; Bryan & Harter, 1899; Kahneman, 1973; LaBerge & Samuels, 1974; Posner, 1978). A consequence of such integration is said to be a "freeing up" of attention. The large units then function to direct the individual through the smaller components, helping on the one hand to maintain performance in the task yet on the other sometimes allowing the individual to pick up additional stimulus information without suffering interference. For example, Neisser & Dube (Note 1) report that in the ball-toss game including the umbrella woman, highly skilled subjects were more likely to notice the unexpected event than were less practiced subjects, but without decreasing in accuracy.

The present hypothesis shares several features with the preceding ideas. Although the process of building a unit structure is presumed to be in large part a conscious, controlled process, having mastered a unit structure which

continues to be employed is hypothesized to be a factor in allowing automatic processing of the lower order components. As noted above, people should become better at maintaining task performance as the unit structure becomes integrated. However, the present hypothesis also predicts what particular points in the stimulus sequence allow greater vulnerability to distraction. A subsidiary prediction is that while establishing a unit structure adequate to a task, the functionally "highest" unit would be lower than is the case after the relevant structure is established. Distractions should have a greater effect at unit boundaries throughout the task. The effect of distractions, however, should gradually cease to be effective at lower order unit boundaries.

Another major hypothesis which stems from the first one will be discussed briefly, for theoretical completeness. It will be tested subsequently, but not in the present study. It seems likely that children become, with age, more able to integrate information into task-relevant structures. In fact, when presented structured stimuli to reproduce or a particular goal to attain, younger children do tend to respond in terms of discrete, unconnected units of information or action, gradually becoming able to integrate such units in task-relevant ways (Bruner, 1973; Goodson &

Greenfield, 1975; Greenfield, Nelson, & Saltzman, 1972; Greenfield & Schneider, 1977; Guttman & Kahneman, 1971; Koslowski & Bruner, 1972). It is hypothesized, then, that given a task involving related, sequentially presented stimuli, younger children will be less apt to integrate stimuli into a structure adequate to task demands. The structures they do attain will have many more breaks which are not for them subsumed in a higher level unit. They will, therefore, be less able to anticipate task-relevant stimuli and responses, and will meet with many more "stops" in processing between units of information. The increased number of "stops" between units may correspond to an increased frequency in the points where the child is vulnerable to distraction. It is a common observation that children become less distractible with age (e.g., Doyle, 1973; Shepp & Swartz, 1976; Smith, Kemler, & Aronfreed, 1975; Strutt, Anderson, & Well, 1975), but the reasons for this change have not been well defined. The general observation has also been made that children's tendencies to be distracted from tasks relates to how their perceptions of the stimulus situation match up with task demands (Gibson, 1978; Gibson & Rader, 1979). Neisser also noted that first grade children were unable to perform his ball-toss task well, which he attributed to the lack of appropriate

schemata to initiate and maintain an effective perceptual cycle. The present hypothesis encompasses these general notions, but offers a specific reason (although not necessarily the *only* reason) for developmental differences in distractibility.

Overview of the experiment. The present study is a detailed investigation of the major hypothesis: that given a task in which hierarchical structures for sequences of stimuli are relevant to effective performance, external distractions affect performance more at the boundaries between units in the structures, with greater effects at higher level boundaries.

Subjects in the experiment were trained to perceive patterns in two sequences of stimulus information. These patterns were defined by formal structures which specified hierarchies of units of information. The training ensured that subjects had access to the experimenter-defined structures; however, subjects were not necessarily facile with these structures at the outset of the experiment.

After training, subjects performed a continuous prediction task in the context of an outer space video game. Sequences of stimuli appearing in the prediction task were in accord with those learned during training. Between sequences, there was always an event which

informed subjects of the next sequence. Its boundaries with the two sequences surrounding it were presumed to be the highest level "breaks" in the structure. Since the task proceeded continuously, subjects were instructed to predict the next stimulus as quickly as possible each time a given response signal occurred on the video screen. If they did not know the identity of the next stimulus, they could respond after it had actually appeared. Response times and errors were recorded. During some presentations (trials), one of several types of distraction occurred in another location on the video screen. Some distractors were assigned to occur within the lowest units in the structure and at the boundaries of all levels in the structure, so that differences in the effects of distractions at the different positions could be compared.

When distractors were presented, they always occurred simultaneously with the response signal. They were presented at this time because it was assumed that any interruptions in integrative processes would occur at this time. (It is also possible that information about the next event is processed in parallel with the ongoing response (Keele & Boies, 1973; Kerr, Blanchard, & Miller, 1980). The effect of a distractor presented on the

preceding trial may thus be of interest.)

Subjects experienced numerous sequences of each type, making possible an examination of changes in the pattern of effects at particular unit levels over the course of the experiment. For example, did the functional high level "break" move higher as the subject became facile with the structures? In addition, some subjects' faces were videotaped as they performed the task, in an effort to gain information about the incidence and duration of eye movements to distractors in relation to their point of occurrence in the unit structure.

CHAPTER II

METHOD

Subjects

Subjects were 57 students at the University of Massachusetts. Of these subjects, nine had difficulty understanding the procedures during the first blocks of the experiment, causing inappropriate responding until their misunderstandings were corrected. In addition, some data of four other subjects were lost due to computer malfunction. All subjects received experimental credit for participation.

Stimuli

The presentation of stimuli was controlled by a Cromemco Z-2D microcomputer system equipped with a color videographics generator (Dazzler) and connected to a 17 in color monitor. The computer also received input from three response buttons. With the Dazzler, the screen of the monitor was effectively a 64 x 64 grid. Each of the 4096 elements of the grid could be filled with any of 16 different colors. When displayed, each element was .16 in (.41 cm) in height and .21 in (.53 cm) in width.

The background color for all stimulus items and for

all periods between stimulus presentations was an unsaturated red-orange (off-white). All stimulus items described below appeared in either the upper or lower half of the screen.

The <u>response signal</u> was roughly circular, and had an overall appearance similar to a radar screen or bull's eye target. It had a maximum height of 2.56 in (6.5 cm) and a maximum width of 3.36 in (8.53 cm). It was composed of sections of dark blue, medium blue, green and the background color. In the lower left-hand corner, one element was filled with black.

<u>Squadron leader 1</u> had a maximum height of 1.6 in (4.1 cm) and a maximum width of 4.2 in (10.67 cm). It, like the other squadron leader and spaceships, was designed to resemble a schematic spaceship. Its upper, winged portion was red; its flat base was blue.

<u>Squadron leader 2</u> had a maximum height of 2.24 in (5.7 cm) and a maximum width of 3.36 in (8.53 cm). Its upper portion, which was the same as for squadron leader 1, was green. Its lower, double-winged portion was purple.

<u>Spaceship 1</u> had a maximum height of 1.92 in (4.88 cm) and a maximum width of 4.2 in (10.67 cm). It had a roughly circular center portion which was purple, and a large, dark blue base.

<u>Spaceship 2</u> had a maximum height of 1.92 in (4.88 cm)

and a maximum width of 4.2 in (10.67 cm). Its center portion (identical to that of spaceship 1) was green, and it had two orange "wings".

The <u>space scene distractor</u> was a schematic outer space display. The background of the scene was dark blue (resembling an evening sky); it filled an entire half of the screen (5.1 in (12.95 cm) by 13.6 in (34.54 cm).) On the left-hand side was a green "planet", which was 1.6 in (4.1 cm) in height and 2.1 in (5.33 cm) in width. There was a yellow crescent "moon" on the right-hand side, which was 1.28 in (3.25 cm) high and .63 in (1.6 cm) wide. There were forty possible locations where white "stars" could be displayed. At any given moment, approximately half of these locations were filled with white. Each star was .16 in (.41 cm) high and .21 in (.53 cm) wide. When this scene was displayed, the program continually updated, by changing a white star to blue and a blue location to white. The overall effect was of "twinkling" stars. Finally, in a path around the planet, one element at a time changed to red, then back to blue, and so on, such that a small red satellite appeared to circuit the planet.

<u>Verbal distractors</u> were selected from a list of 128 words, colloquial expressions, and phrases which were stored in the computer. They were a minimum of four

characters and a maximum of six characters in length. The maximum height of each character was 1.12 in (2.84 cm) and the maximum width was 1.05 in (2.67 cm). Each time a verbal distractor was presented, the color of the characters was randomly selected from all colors distinct from the background. Examples of verbal distractors included:

uh-oh!	dummy	warp 6	bored?	no way
relax	tired?	jerk!	take 5	oops!

(The messages were represented as "enemy interference".)

The <u>flying ball distractor</u> resembled the tennis or ping pong "balls" commonly seen in video games; however, the direction and speed of its "movement" were controlled by random selections of directions and velocities on the x- and y-axes. The color of the .16 in (.41 cm) by .21 in (.53 cm) "ball" was randomly selected from those colors distinct from the background. The "movement" of the ball was created by filling and unfilling successively chosen elements at the selected velocities. The variation in velocities caused the ball to at times appear to drift across the screen, and at times appear to zoom or flash across the screen.

When one of the three distractors was presented, it always appeared in the opposite half of the screen from the response signal, squadron leader, or spaceship. The minimum distance between an edge of one of the latter

and a distractor was 1.12 in (2.84 cm).

Design

Each subject experienced 30 instances of each of two possible stimulus sequences, divided into 10 blocks with a rest period between each block. Each of the six instances within a block was randomly selected from the two sequences, the only constraint being the limit of 30 of each sequence over the entire experiment. Each presentation of an event in a sequence constituted a trial.

The sequences were generated from a modification of Restle's (Restle, 1970; Restle & Brown, 1970) system for representing sequential stimuli. Two operations defined in this system are repetition (R) and transposition (T). R(x) signifies "start the sequence with x and repeat x". T(x) means "start the sequence with x and add x+1". Likewise, -T(x) means "start the sequence with x and add x-1". The operations can be tested: R(T(x)) = x, x+1, x, x+1. They can also be repeated in a non-nested fashion, using subscripts: $R(T_2(x))$ = x, x+1, x+2, x, x+1, x+2. (In Restle's usage, these rules are applied to sequences of six lights or six musical notes, and thus the numbers represent each event in the set of six. In the present application to binary stimuli, the numbers generated always signify the number of repetitions of

a particular spaceship before a change to the other spaceship (given an arbitrary starting point).)

Sequence 1 was defined as follows:

$T_2(R(R(1)))$ =

1 1 1 1 2 2 2 2 3 3 3 3

Beginning with spaceship 1, that structure translated into the following sequence of spaceships:

1 2 1 2 1 1 2 2 1 1 2 2 1 1 1 2 2 2 1 1 1 2 2 2

Sequence 2 was defined as follows:

$-T_3(R(4))$ =

4 4 3 3 2 2 1 1

Beginning with spaceship 2, that structure translated into the following sequence of spaceships:

2 2 2 2 1 1 1 1 2 2 2 1 1 1 2 2 1 1

A presentation of sequence 1 was always immediately preceded by the appearance of squadron leader 1, while sequence 2 was always preceded by squadron leader 2. Thus the appearance of a particular squadron leader informed the subject which sequence was about to begin.

Tables 1 and 2 present the unit level corresponding to each event in the sequences. The unit levels were assigned in terms of the level of the unit boundary which a given event followed. For example, in sequence 1, level 1 units follow boundaries between components of the innermost repetition, level 2 boundaries between the

TABLE 1

EVENT, UNIT LEVEL, AND NUMBER OF DISTRACTORS PRESENTED AT EACH POSITION SEQUENCE 1

Position and Event		Unit Level	Number of Distractors
1	Squadron Leader 1	e	12
2	Spaceship 1	b	12
3	Spaceship 2	1	5
4	Spaceship 1	2	10
5	Spaceship 2	1	5
6	Spaceship 1	3	12
7	Spaceship 1	w	4
8	Spaceship 2	1	5
9	Spaceship 2	w	4
10	Spaceship 1	2	10
11	Spaceship 1	w	4
12	Spaceship 2	1	5
13	Spaceship 2	w	6
14	Spaceship 1	3	12
15	Spaceship 1	w	2
16	Spaceship 1	w	4
17	Spaceship 2	1	5
18	Spaceship 2	w	2
19	Spaceship 2	w	4
20	Spaceship 1	2	10
21	Spaceship 1	w	2
22	Spaceship 1	w	2
23	Spaceship 2	1	5
24	Spaceship 2	w	2
25	Spaceship 2	w	6

TABLE 2

EVENT, UNIT LEVEL, AND NUMBER OF DISTRACTORS
PRESENTED AT EACH POSITION
SEQUENCE 2

Position and Event		Unit Level	Number of Distractors
1	Squadron Leader 2	e	13
2	Spaceship 2	b	13
3	Spaceship 2	w	2
4	Spaceship 2	w	2
5	Spaceship 2	w	4
6	Spaceship 1	1	8
7	Spaceship 1	w	2
8	Spaceship 1	w	2
9	Spaceship 1	w	4
10	Spaceship 2	2	11
11	Spaceship 2	w	2
12	Spaceship 2	w	4
13	Spaceship 1	1	8
14	Spaceship 1	w	2
15	Spaceship 1	w	4
16	Spaceship 2	2	11
17	Spaceship 2	w	4
18	Spaceship 1	1	8
19	Spaceship 1	w	4
20	Spaceship 2	2	11
21	Spaceship 1	1	8

second level of repetition, and level 3 boundaries between transpositions. (Note that sequence 2 has no level 3 units; its level 1 units correspond to breaks between repetitions, and its level 2 units breaks between the transpositions.) The boundaries preceding the squadron leader and the first spaceship in the sequences are labeled "e" and "b", respectively, because they are special unit boundaries, indicating a major break in structure. The "e" unit boundary signifies the end of a sequence, requiring a break out of the present structure. The "b" unit boundary signifies the beginning of an entire sequence, using the information provided by the squadron leader.

Distractors were presented on 20% of all trials. When a distractor was presented, the type of distractor was randomly selected from the three possibilities: the space scene, a verbal distractor, or the flying ball.

Because a major purpose of this experiment was to compare the effects of distractors over different unit levels, the assignment of distractors to positions within sequences was very important. A distractor was defined to occur at a particular unit level if it occurred on a trial following a boundary of that level. Of 750 sequence 1 positions occurring during the experiment, distractors occurred on 24 of 60 (40%) b and e

units, 24 of 60 (40%) level 3 units, 30 of 90 (33.3%) level 2 units, 30 of 180 (16.7%) level 1 units, and 42 of 360 (11.7%) "within unit" (w) positions. Of 630 sequence 2 positions, distractors occurred on 26 of 60 (43.3%) b and e units, 33 of 90 (36.7%) level 2 units, 32 of 120 (26.7%) level 1 units, and 36 of 360 (10%) w positions.

The number of distractors assigned to each individual position in each sequence is shown in Tables 1 and 2. The distribution of distractors within a particular unit level was not totally uniform. This was so that effects of distractors occurring on trials preceding unit boundaries could be taken into account. For example, because there were fewer positions at high level boundaries, there were more distractors assigned to within unit positions preceding high level boundaries than to within unit positions preceding other within unit positions.

Each subject received exactly the indicated number of distractors at each position of each sequence, but in different orders. This was accomplished by using a 30 (instances of a sequence) by 25 or 21 (positions within a sequence) matrix for each sequence. At each position, the instances to have distractors were randomly selected. For example, in sequence 1, the squadron leader position

had distractors on 12 of 30 instances. Twelve random numbers between one and thirty were selected, without replacement. The instances corresponding to those twelve numbers were assigned distractors. This process continued until all positions of both matrices were filled. Thus, for each instance of a sequence, there was a set of positions designated to have distractors. When the program which controlled the experiment selected one of the two sequences to be presented, it randomly selected one of the 30 instances from the matrix (without replacement), and displayed distractors at the positions designated for that instance.

Procedure

Each subject was seated in a comfortable chair approximately one meter (m) from the screen of the color monitor. Mounted above the monitor was an RCA TC1005 videocamera directed at the subject's face. The subject's head and body were not restrained. The subject was given the written instructions, the demonstration of the stimuli, and the training on each sequence which are presented verbatim in Appendix A. After training, subjects were shown all the stimulus items again and were given an opportunity to identify them and to rehearse the sequences. If the subject was being videotaped, the camera was

adjusted to make certain that the subject's eyes were in view when the subject assumed a comfortable position for playing the game. The experimenter then began recording and initiated the first game. During breaks between blocks, the experimenter answered subjects' questions and gave feedback concerning the maximum score for a block.

Each trial within a sequence began with the appearance of the response signal. It was displayed for 500 msec in either the upper or lower half of the screen. The location was randomly determined. The "event" for that trial (spaceship or squadron leader) replaced it on the screen, remaining on until 100 msec after the subject responded correctly. (If the subject responded correctly before the event appeared, the event was displayed for 100 msec.) If a distractor was shown on a trial, it appeared in the opposite half of the screen simultaneously with the onset of the response signal, and remained on the screen until the event disappeared. The next trial began after an intertrial interval (ITI) which varied randomly between 100 and 1100 msec. Although the actual ITI was known, it varied as much as 16 msec from the predetermined ITI. Variation in the timing was due to the fact that the trial display began at the top of the horizontal "sweeps" which made up a video image. After all trials of six sequence instances were completed, the

subject's score for the block (based on speed and accuracy) was displayed on the screen. A short rest period was provided between blocks.

For each trial, the computer recorded whether or not there was a distractor and, if so, which type of distractor; the time of onset of the response signal; the event displayed and the time of its onset; responses and the time(s) of their occurrence. The recording of response times was accurate to 10 msec. Because updating the distractor during a trial (e.g., maintaining the "movement" of the flying ball) required time, responses on trials with distractors would normally be recorded up to approximately eight msec late. In order to eliminate a bias toward longer response times on these trials, a 10 msec waiting period between checks for responses was built into the program. Thus, all responses were recorded on the average five msec later than their true average, but there were no systematic biases.

The picture of the subject's face from the videocamera and the image displayed on the screen were routed through a screen splitter and videotaped with a SONY BVU200A video cassette recorder. The screen splitter was set such that the subject's face occupied most of the recorded image, and a narrow band of the image from the screen occupied the remainder. The black dot in the

corner of the display of the response signal was visible in this band. Its appearance indicated the beginning of each trial. Thus, it provided a reference point for synchronizing the detectable eye movements of the subjects with the occurrences on each trial.

CHAPTER III

RESULTS AND DISCUSSION

Overall Analyses

The major hypothesis of the experiment is that subjects' susceptibility to distraction during task performance depends on the structure of the task: Given a task in which hierarchically structured sequences of stimuli are relevant to effective performance, external distractions affect performance most at the boundaries between the highest level structural units. The first step in testing this hypothesis was to examine the effects of unit structure and distraction in analyses of variance. These analyses also considered the effects of practice in the task. Sequence 1 and sequence 2 were analyzed separately, essentially considered as replications of the experimental design. The thirteen subjects whose data were incomplete were eliminated from these analyses.

Three dependent measures were analyzed: time to respond correctly (RT) on errorless trials; RT on all trials (including those where the correct response was not made first); and error rate (the number of errors divided by the number of responses). The

independent variables in each analysis were block, distraction, and unit level. Because the presentation of the two stimulus sequences was mixed within blocks in the experiment, blocks were defined for purposes of analysis as five sets of six instances of a particular sequence (e.g., the first six instances of sequence 1 presented to a given subject comprised block 1, sequence 1). Distraction was defined as present or absent on a given trial, regardless of type of distraction. The unit level of a trial was specified as described in the Design subsection, with six unit levels defined for sequence 1 and five levels for sequence 2. For each subject, mean scores for all trials within a particular block, distraction condition, and unit level were computed. Thus, sixty scores were entered for each subject into three blocks (5) x distraction condition (2) x unit levels (5 or 6) analyses of variance. Empty cells occurred for some subjects, particularly in the errorless trials analysis. In these cases, the missing data was replaced with mean scores and appropriate adjustments in degrees of freedom were made. Planned comparisons are Bonferroni F-tests; the experiment-wise error rate (EW) does not exceed .10. The complete analysis of variance tables appear in Appendix B.

Reaction time analyses. In general, results for errorless

trials and for all trials were in agreement. Because RTs on errorless trials were less variable and because they were likely to be a better reflection of the process of preparing a response given knowledge of the unit structure, only the findings for this measure are reported in detail. Major discrepancies between the results for errorless trials and all trials are noted.

Unit level. Mean RTs for each unit level in sequence 1 and sequence 2 are presented in Table 3. RT varied significantly across unit levels (sequence 1: $F(5,215) = 31.30$, $p < .001$; sequence 2: $F(4,172) = 33.53$, $p < .001$). Pairwise comparisons between adjacent members of the unit hierarchies revealed that for sequence 1, RTs on level e trials were significantly greater than on level b trials, $F(1,43) = 14.51$, $EW < .002$, which were in turn greater than on level 3 trials, $F(1,43) = 44.73$, $EW < .001$. RTs on unit 1, unit 2, and unit 3 trials were not significantly different from one another, but were all significantly greater than RTs on unit w trials, $F(1,43) = 8.78$, $EW < .02$. For sequence 2, RTs at each unit level were significantly greater than at the next level in the hierarchy ($F = 14.51$, $EW < .002$; $F = 13.32$, $EW < .002$; $F = 47.91$, $EW < .001$; $F = 5.44$, $EW < .10$; $F = 6.10$, $EW < .05$, respectively; all F's on 1,43 df).

TABLE 3

MEAN RTS (MSEC) FOR EACH UNIT LEVEL
SEQUENCE 1 AND SEQUENCE 2

Unit Level		E.	B	3	2	1	W
Sequence	1	1075	682	478	467	470	442
	2	1033	686	---	468	447	408

Distraction. Mean RTs in the presence and in the absence of distraction appear in Table 4. RTs were significantly greater when distraction was present than when it was absent, for both sequence 1, $F(1,43) = 8.40$, $p < .006$, and sequence 2, $F(1,43) = 7.05$, $p < .011$. For sequence 1, 39 of 44 subjects responded more slowly in the presence of distraction; 32 of 44 subjects did so for sequence 2. (In the analysis of all trials, the distraction effect was not reliable for sequence 2.)

The findings reported thus far indicate that subjects' speed in performing the classification/prediction task corresponds fairly well with the levels of units in the hierarchically-defined structures. As expected, more time is required to prepare a response following a high level break in the unit structure than to prepare a

TABLE 4

MEAN RTS (MSEC) FOR EACH DISTRACTION CONDITION
SEQUENCE 1 AND SEQUENCE 2

Distraction Condition		Present	Absent
Sequence	1	629	576
	2	626	591

response within a low level unit. The distractions also apparently provide effective interference with the speed of performance. The central question in the study, however, is whether these two variables interact. Mean RTs at each unit level in both distraction conditions are presented in Table 5. As can be seen in Table 5, the effect of distraction did not vary systematically over the unit levels of either sequence (sequence 1: $\underline{F}(5,215) = .08$; sequence 2: $\underline{F}(4,172) = 1.52$), and actually reversed sign at the highest unit level of sequence 2. The same pattern obtained for the all trials analysis. Thus, there is no evidence of the predicted relationship between unit level and the magnitude of the distraction effect.

In addition to the findings reported above, there

TABLE 5

MEAN RTS (MSEC) AS A FUNCTION OF EXPERIMENTAL CONDITION SEQUENCE 1 AND SEQUENCE 2

Unit Level		E	B	3	2	1	W
Sequence 1							
Distraction	Present	1108	714	500	488	493	470
	Absent	1043	649	456	447	448	413
Difference		65	65	44	41	45	57
Sequence 2							
Distraction	Present	1019	714	---	486	481	429
	Absent	1046	658	---	450	414	386
Difference		-27	56	---	36	67	43

were effects of practice on performance for both sequences. Subjects' RTs decreased with practice (sequence 1: $\underline{F}(4,172) = 87.89$, $\underline{p} < .001$; sequence 2: $\underline{F}(4,172) = 58.48$, $\underline{p} < .001$). There was also a blocks x units interaction for sequence 1, $\underline{F}(20,860) = 6.29$, $\underline{p} < .001$, and for sequence 2, $\underline{F}(16,688) = 6.91$, $\underline{p} < .001$. As seen in Tables 6 and 7, the difference in RTs between the unit levels is greater at the outset of the session than at its end due to larger practice effects for the higher level units (sequence 1: $\underline{F}(5,215) = 10.43$, $\underline{EW} < .001$ for the units x blocks (linear) interaction; sequence 2: $\underline{F}(4,172) = 12.02$, $\underline{EW} < .001$).

Error rates. The mean error rate over all trials was .0635 for sequence 1 and .0608 for sequence 2. In general, the pattern of results for errors is similar to that reported for the RT analyses. There were significant effects of unit level for both sequence 1, $\underline{F}(5,215) = 21.57$, $\underline{p} < .001$, and for sequence 2, $\underline{F}(4,172) = 17.90$, $\underline{p} < .001$. Mean error rates over unit levels are presented in Table 8. The same pattern of differences between adjacent members of the unit hierarchy was obtained as in the RT analysis (all $\underline{F}$'s > 5.18, $\underline{EW} = .10$ or less), with one exception: For both sequences, error rates were greater for unit 1 than for either unit 2

TABLE 6

MEAN RTS (MSEC) AS A FUNCTION OF EXPERIMENTAL CONDITION
SEQUENCE 1

Unit Level		E .	B	3	2	1	W
	1	1935	1198	752	736	749	686
	2	1044	703	470	455	435	431
Blocks	3	884	573	406	405	410	383
	4	797	488	389	375	389	356
	5	717	446	375	365	368	353

TABLE 7

MEAN RTS (MSEC) AS A FUNCTION OF EXPERIMENTAL CONDITION
SEQUENCE 2

Unit Level		E	B	2	1	W
	1	1709	1288	731	706	602
	2	1055	674	450	434	394
Blocks	3	916	546	401	368	351
	4	787	467	386	367	347
	5	696	455	374	361	344

TABLE 8

MEAN ERROR RATES AS A FUNCTION OF UNIT LEVEL
SEQUENCE 1 AND SEQUENCE 2

Unit Level		E	B	3	2	1	W
Sequence	1	.136	.088	.019	.027	.078	.033
	2	.123	.059	----	.026	.078	.019

(sequence 1: $\underline{F}(1,43) = 42.04$, $\underline{EW} < .001$; sequence 2: $\underline{F}(1,43) = 33.92$, $\underline{EW} < .001$) or unit w ($\underline{F}(1,43) = 41.48$, $\underline{EW} < .001$ for sequence 1; $\underline{F}(1,43) = 46.37$, $\underline{EW} < .001$ for sequence 2). Unlike the RT analysis, there was no effect of distraction in either sequence. There was, however, a significant unit level x distraction interaction for sequence 2, $\underline{F}(4,172) = 4.00$, $\underline{p} < .004$. However, this interaction was opposite the predicted direction. Error rates were significantly lower in the presence of distraction for units e and b, $\underline{F}(1,43) = 6.15$, $\underline{EW} < .05$. This effect was strongest early in the experiment, $\underline{F}(20,860) = 3.52$, $\underline{p} < .001$.

Similar to the RT analysis, there were also significant effects of blocks (sequence 1: $\underline{F}(4,172) = 26.35$, $\underline{p} < .001$; sequence 2: $\underline{F}(4,172) = 35.65$, $\underline{p} < .001$) and

interactions of blocks with unit levels ($F(20,860) = 3.51$, $p < .001$ for sequence 1; $F(16,688) = 5.50$, $p < .001$ for sequence 2). Error rates declined over the course of the experiment, but the practice effect was again greater for high level units than for low level units ($F(5,215) = 7.16$, $EW < .001$ for the sequence 1, units x blocks (linear) interaction; $F(4,172) = 10.58$, $EW < .001$ for the sequence 2, units x blocks (linear) interaction).

Summary and discussion. The combined results from the RT and error rate analyses support the notion that the hierarchy of unit levels as defined are psychologically real for these subjects. As shown by increased RT and errors, preparing for the squadron leader signal or for the beginning of a new sequence is a more difficult transition for the subjects than continuing within a unit or making a lower level transition. The difference in performance may be more than a matter of the responses being difficult, however. Subjects may also use these transition points as pieces of information around which to organize their expectations about the stimuli to follow. It is also apparent that subjects made progress in integrating the larger segments of the structure more readily, as demonstrated by the blocks x unit structure

interactions. Nevertheless, it should be noted that even during the last block of the experiment responses to unit e trials were made on the average of nearly 250 msec after the time when the actual stimulus event appeared, indicating that subjects still experienced difficulty anticipating it.

Despite evidence supporting the influence of the hierarchical unit structure on performance, there was no confirmation of the major hypothesis that distraction would be greater at the high level unit boundaries. This was certainly not due to the absence of an overall distraction effect, since distractions interfered with RT performance throughout the experiment. It was proposed earlier that distractions presented before a unit boundary might actually be more disruptive to processes occurring between units. This possibility will be examined further in the next section.

Prediction of Response Times

Description of the analyses. The analyses discussed thus far are limited in certain respects. A large amount of the available data (13 subjects out of 57) were discarded because they did not meet the requirements of the analysis of variance design. In addition, other independent variables were manipulated in the experiment, but were

difficult or impossible to test within the scope of the analysis of variance design. One variable which has already been discussed is the effect of distraction occurring on the trial preceding the trial of interest. Another variable even less suited to the analysis of variance design is intertrial interval, which, it will be recalled, varied randomly between 100 and 1100 msec. In order to consider the effects of such variables and to take advantage of the maximum amount of useable data, the data were subjected to multiple regression analyses. In these analyses, sequence 1 and sequence 2 were again analyzed separately. RT on each errorless trial was the dependent variable; the predictor variables entered tested specific effects of interest. These predictor variables are described in detail below. Because each trial was entered separately, the useable data from the 13 subjects eliminated earlier were added to these analyses.

The first independent variable entered in all the regression analyses was each subject's average RT. This served to extract between-subjects variance from the total variance in RT, allowing tests of the within-subjects main effects of interest to be based on the appropriate residual error term (Cohen & Cohen, 1975). The main effects included: (1) trial number: the number of trials the subject had experienced; (2) distraction-now: distraction

present or absent on the trial predicted; (3) distraction-past: distraction present or absent on the trial previous to the predicted trial; (4) error-past: an error was made on the previous trial (which is obviously not truly an independent variable); (5) intertrial interval: defined as the time between when the display for the previous trial ended and when the response signal for the present trial appeared; and (6) unit level. Because unit level was a multi-level variable but was not on an interval scale, it was recoded according to effects coding (Cohen & Cohen, 1975), yielding five variables for sequence 1 and four variables for sequence 2. All other categorical variables (distraction-now, distraction-past, and error-past) were also effects coded (e.g., 1, -1).

Results of the analyses. All main effects were tested by first entering subjects' average RT, then evaluating the main effect in terms of its further contribution to the regression equation. Table 9 summarizes the results of testing each of the main effects for sequence 1 and sequence 2. The number of cases entering into the sequence 1 analysis is 40,023 and for sequence 2 is 34,036. With such a large number of observations, it is apparent that the contribution of a variable can be highly significant while only slightly changing R^2. In this analysis,

TABLE 9

RESULTS OF REGRESSION ANALYSES PREDICTING
RT ON ERRORLESS TRIALS
SEQUENCE 1 AND SEQUENCE 2

Sequence	Variable	R	R^2	df	F
	Subject RT	.132	.017	2,40021	704.9
	Trial Number	.253	.064	2,40020	1991.1
	Distraction-now	.156	.024	2,40020	282.9
1	Distraction-past	.133	.018	2,40020	12.9
	Error-past	.182	.033	2,40020	652.7
	Intertrial Interval	.171	.029	2,40020	497.6
	Unit Level	.281	.079	2,40016	536.6
	Subject RT	.241	.058	1,34034	2104.2
	Trial Number	.315	.099	2,34033	7551.2
	Distraction-now	.264	.070	2,34033	421.3
2	Distraction-past	.243	.059	2,34033	27.6
	Error-past	.270	.073	2,34033	542.4
	Intertrial Interval	.277	.077	2,34033	678.4
	Unit Level	.394	.155	5,34030	978.3

all of the main effects were significant predictors of RT; however, the proportion of variance accounted for by all of the main effects simultaneously is only .138 for sequence 1 and .221 for sequence 2.

The pattern of results for the main effects was identical for sequence 1 and sequence 2. Trial number, distraction-now, and unit level are essentially redundant with the analysis of variance. They show that RT decreased as practice increased, that distraction interfered with performance, and that there was significant variation in RT over unit levels. The other three variables provided new information. Distraction on the previous trial had a small but significant interfering effect on RT, and having made an error on the previous trial also slowed RT. RTs became shorter as intertrial interval increased, indicating subjects used the available time to prepare responses.

Interactions of interest were tested by creating a new variable (or variables if unit level was a component of the interaction) which was the product of its main effect components. Each interaction variable was then tested by entering it into the equation after average RT and the component effects of the interaction.

Examination of the relationship between distraction and unit structure revealed results little different from

those obtained in the analysis of variance. As in the latter analysis, the relationship between distraction on the present trial and unit level was not significant. This result is all the more striking in the present context considering the tremendous power of this analysis. The relationship between distraction of the preceding trial and unit level was also not significant for sequence 1, but a significant relationship was found for sequence 2, $\underline{F}(10,34025) = 3.8295$, $\underline{p} < .001$, $R^2 = .00038$). Inspection of the B coefficients indicated that this effect is not due to a systematic increase or decrease in the distraction effect over the unit levels, but represents a significant and not particularly meaningful fluctuation in the magnitude of the distraction effect over unit levels.

Another variable of some interest is the intertrial interval. There was a significant interaction of intertrial interval with unit levels (sequence 1: $\underline{F}(12,40010) = 13.39$, $\underline{p} < .001$, $R^2 = .00152$; sequence 2: $\underline{F}(10,34025) = 5.63$, $\underline{p} < .001$, $R^2 = .00055$), which appeared to be due to a greater advantage of longer intertrial intervals for lower order units. Intertrial interval also interacted with distraction-now (sequence 1: $\underline{F}(4,40018) = 65.44$, $\underline{p} < .001$, $R^2 = .00157$; sequence 2: $\underline{F}(4,34031) = 12.49$, $\underline{p} < .001$, $R^2 = .00033$), but the effect differed in direc-

tion for sequence 1 and sequence 2. For sequence 1, longer intertrial intervals provided a greater advantage when there was no distraction; the reverse was true for sequence 2. The interaction between distraction-past and intertrial interval was not reliable for sequence 1, but there was a small effect for sequence 2, $F(4,34031) = 2.54$, $p < .05$, $R^2 = .00007$, of a greater advantage from longer intertrial intervals when distraction was present on the preceding trial. A summary of all interactions tested is presented in Appendix C. It should be noted that all significant interaction effects produced only very small changes in R^2. These variables should not, then, be regarded as particularly important in predicting RT results, but should be noted as having small but reliable effects.

Summary and discussion. Overall, the new information yielded by the regression analyses is slight. No new support has been provided for the central hypothesis concerning the relationship between the unit structure and distraction. A few variables not included in the analysis of variance were shown to contribute significantly to explaining the variance in RT. The occurrence of an error or a distraction on the preceding trial was likely to lead to increased RTs on the predicted trial.

The amount of time available between trials also had a significant effect, with RTs decreasing as more time was provided to prepare a response between trials. The inter-trial interval variable interacted with distraction and with unit level, but not in a consistent way between the sequences; for this reason, these interactions should perhaps be regarded as less generalizable than effects where agreement between the sequences was obtained.

Overt Eye Movements

Viewing a sample of the videotapes revealed that subjects made very few observable eye movements towards the distractors. The videotapes were subjected to no further analysis.

CHAPTER IV

GENERAL DISCUSSION

Accomplishments of the Experiment

The results of the present experiment provide evidence of the influence of perceived structures in sequences of stimuli on performance of a classification/prediction task. On trials following boundaries between units higher in the hierarchical structure, subjects' responses are slower and less accurate. This finding indicates that the structures as defined are psychologically real for the subjects: the higher the level of the boundary, the more information they must integrate in order to produce the response and perhaps prepare for future responses. Subjects apparently improve their ability to make the more complex integrations, as RTs and error rates decrease more steeply for higher level units.

The findings also indicate that the distractors used in the present experiment effectively impede performance. Subjects are reliably slower to respond when distraction is present, and the distraction effect remains relatively constant throughout the experiment.

Although both the unit structure and the presence

of distraction affect performance, there is not a hint of confirmation of the hypothesis that vulnerability to distraction depends on unit level within a structure. Given that the regression analyses are powerful enough to detect even very small effects, the null results in this case are indeed compelling.

Theoretical Significance of the Results

Alternatives to the present hypothesis. The most straightforward interpretation of the present results is that the effects of irrelevant information on performance are unrelated to the organization of an individual's task. Whereas the organization of the task and stimuli associated with the task may affect the pattern of responding across time, irrelevant stimuli may have strictly momentary effects. That is, when irrelevant stimuli are present their effect may depend on their relationship with an immediately present relevant stimulus, but will not depend on how that relevant stimulus fits into a whole pattern of events.

There are a number of ways in which such momentary effects may occur. When irrelevant stimuli are present, they may elicit an orienting response (Sokolov, 1963), thus delaying the relevant response. Interference, then, would depend on the potency of the irrelevant stimuli to

elicit an orienting response. Lorch, Anderson, & Well (Note 2) found evidence to support the notion that subjects learn to selectively attend in specific situations by habituating such responses to irrelevant stimuli. No evidence for habituation of responses was found in the present study, but would not be expected in these circumstances. In the present study, there is a great deal of variety in the distractors. They change location randomly from trial to trial. There are three very different types of distractors, and there is also a great deal of within-type variability in the distractors. For example, no word is ever seen twice and the words are shown in different colors; the flying ball moves in random directions and at random velocities; and the space scene provides a sudden change in the stimulus field and then continues to change internally. With this variety of stimulation, it would be predicted that orienting responses to the distractors would be very slow to habituate. This prediction is supported by the results of the present study, in that the effect of distraction remained relatively constant across the experiment.

Another way in which momentary effects may occur is that it may be necessary to sort or distinguish relevant from irrelevant stimuli in order to perform the task. That is, given an immediately present display

containing relevant and irrelevant information, the subject may need time to identify what information should be used and what should be discounted, or time to perceive the relevant information accurately given the presence of the irrelevant information. As in the case of the orienting response mechanism, subjects might be expected to improve their speed of making these discriminations if the same irrelevant background appeared repeatedly, but not if the irrelevant stimuli continued to change.

A final comment concerns the relationship between the present study and Neisser & Dube's (Note 1) work on the maintenance of perceptual cycles when distractions are present. Their interpretations could be restated as indicating that, when subjects are integrating information without discernible breaks in processing, they are both unaffected by and usually unaware of the presence of a distraction. This interpretation would be consistent with the major hypothesis tested in the present study. The results of this study give force to certain criticisms of Neisser & Dube's research. Their conclusions are based on accuracy data and on the subjects' reports of what they observed during the task. Although the present task is very different in structure, the results would have been quite similar to Neisser & Dube's had the data been restricted to their measures. Accuracy was not significantly

affected by the presence of distraction. Subjects reported that the present task was entirely absorbing, requiring a great deal of concentration and minimizing conscious awareness of any information irrelevant to task decisions. Although the subjects were told the distractors would appear and were virtually forced to look at them, most could give little information about their appearance. For example, few could report more than two or three of the words, almost no one identified the space scene beyond being able to report that more than half the screen turned blue, and many subjects were totally unaware of the flying ball. Most subjects were also convinced that the distractors did not affect their performance, except possibly in the first block or two of the experiment. Excluding the RT data, these results accord well with Neisser & Dube's conclusion that subjects doing an absorbing task do not experience distraction. The RT data, however, reveal a different pattern, and one which has implications for Neisser & Dube's earlier conclusions.

Limitation of the test of the major hypothesis. It was pointed out earlier that the results of the present study establish the psychological reality of the formally defined unit structures. The nature of that reality is

that subjects apparently spend more time integrating information across boundaries, the higher the level of the boundary in the structure. Although this finding establishes the influence of the structures, it may not actually establish an adequate condition for testing the major hypothesis.

Recall that the major hypothesis is based on the idea that subjects are less distractible within a well-differentiated unit structure because they are actively integrating information, and that they are most distractible when they reach a unit boundary across which they cannot or do not integrate (e.g., up to a unit level which they are unable to reach). This is also the point of the developmental prediction: that children will come to the point beyond which they are unable to integrate at a lower point in the "real" unit structure than do adults, and so will have more frequently occurring points when they are vulnerable to distraction. The problem in the present study is that the subjects may not have been presented with any points across which they could not integrate, only points across which it became more difficult to integrate. Although the subjects required more time to cross high level unit boundaries, they may have remained fully engaged in information integration.

In the design of the study, the boundary preceding

squadron leader trials was expected to be a boundary preventing further integration, and therefore to provide an adequate test of the hypothesis. In practice, however, two problems may have occurred. First, subjects had the information necessary to predict "squadron leader", and so were not actually prevented from dealing with expected information. Secondly, some subjects reported developing a strategy of purposely allowing a squadron leader display to remain on the screen, only responding when they had determined the characteristics of the sequence which was to follow. Using such a strategy could result in distraction effects being attenuated for these trials, since subjects may have delayed responding independently of the appearance of distraction.

Retesting the major hypothesis. The primary condition to be met in order to better test the hypothesis is to ensure that subjects are unable to integrate information across the highest level unit boundaries used in the study. One possibility for meeting this condition is the following: Subjects are trained to perceive a particular sequence structure, such as one of those used in the present study. They then perform a classification task, similar to the one used here except that they are not

permitted to predict the upcoming stimulus, only to respond to it after it appears. While a particular condition holds true (e.g., the background color is green), the structure they have learned will determine the sequence of stimuli. While another condition holds (e.g., the background color is orange), the sequence of stimuli will be randomly determined. The screen can change color at any time. Time between trials is varied systematically, and irrelevant stimuli from a variety of possibilities are shown on some trials.

It is obvious that under these conditions, subjects would classify more quickly while the structure they have learned applies than when the sequence is random, since they can prepare their responses. It would also be expected that the difference in response times under these two conditions would increase as the intertrial interval increased (at least until the response in the structured condition was fully prepared). The predictions that the major hypothesis of this dissertation would add are that (1) the effect of distraction will be less in the structured than in the random condition; and (2) the difference in the effect of distraction will show a different relationship with intertrial interval than that for response times. Because distraction is expected to be less in the structured condition due to ongoing integra-

tion of information, its effect should not be related to the degree of integration accomplished (unless the process has not begun or is totally complete). Therefore, instead of the continuous relationship expected between intertrial interval and the structured - random difference for response times, this function would be expected to be flat or discrete.

The study proposed above would also, of course, serve as a means to partially replicate the experiment reported in this dissertation. If an appropriate context and stimulus sequence were selected, it could also serve as the basis for a test of the developmental hypothesis. If school-age children were included and if a group of subjects at each age were not pretrained, the following questions could be approached: For adults who are not pretrained, are the effects of distraction in the structured and random conditions more similar at the outset of the experiment than at its end? Do children who are pretrained perform similarly to adults? Do children who are not pretrained show no difference in the effects of distraction between the structured and random conditions?

The hypothesis might also, of course, be retested in situations other than that outlined here, including situations where information and behavior is more meaningful and realistic. Examples would include: the building

of complex physical structures, the processing of prose, and the processing of televised materials. As discussed in Chapter I, ways of defining structures in these kinds of situations have begun to be developed and tested. It may be important to test the hypothesis under such conditions of customary information processing.

A final possibility is that the hypothesis not be discarded but that it undergo considerable modification. The importance of the effects of distraction in testing people's abilities to maintain attention may be overemphasized in the present study. Part of the ability demanded when maintaining attention is simply to keep attention to one's purposes, regardless of whether the environment includes distractions or is unchanging. The best test of the hypothesis (particularly developmentally) may be one which does so without reference to distraction.

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APPENDIX A

INSTRUCTIONS AND TRAINING PROCEDURE

Written Instructions

In this experiment, you will be playing an outer space video adventure game. I will be videotaping you with the camera behind the TV set as you play the game. As you might expect in a video adventure game, you are part of a fleet engaged in mythical warfare with another fleet of ships. Each time you are given a certain signal on the TV screen, you will have to tell your starbase which of two "spaceships" is approaching, or (less frequently) if one of two "squadron leaders" is approaching. You will do this by pressing one of three push-buttons. Before you begin playing the game, I will be teaching you rules for the sequences of spaceships and squadron leaders which you'll see. If you remember these rules, you should always be able to predict what will appear.

Once the signal to predict the approaching ship has been given, you should try to respond as quickly and as accurately as you can. A short time after the signal to respond has been shown, the spaceship or squadron leader will replace the signal on the screen. If you have not had time to respond, you should still do so as quickly as possible. You are given points for any correct information you provide for your starbase, but you earn

more points if you respond before the spaceship or squadron leader appears on the screen (your starbase is able to complete an attack or defense). You should try to be accurate as well as fast, since errors will cause you to be penalized; the penalty will be greater if the error is made before the spaceship or squadron leader appears. In other words, you earn more points for fast, correct responses but you lose more points for fast, incorrect responses. There is no difference in amount of points earned for reporting squadron leaders or spaceships. You will have rest periods during the experiment; you will have a chance to see your score at these times.

The signals to respond and the spaceship or squadron leader will appear in one half of the TV screen, sometimes the upper half and sometimes the lower half. In the other half of the screen, from time to time other displays will appear. These represent interference from your "enemy", so you should ignore them and try to maintain fast and accurate responding on the game.

Training Procedure

(The subject is handed a box with the three pushbuttons which are connected to the computer. The screen is displaying the background color.)

Here are the buttons you'll be using to make your responses in the game. As it said in the instructions, there will be two different squadron leaders, which you'll see in a few minutes. For either one of these, you press the button in the middle marked S. You'll also be seeing two different spaceships. One we'll call spaceship 1; you'll use the button marked 1 to make a response for it. The other we'll call spaceship 2; you'll make a response for it with the button marked 2. Let's look at some of the things you'll see during the experiment.

(The response signal is displayed (all items appear in the lower half of the screen during the demonstration).)

This is going to be your signal that a spaceship or squadron leader is going to appear on the screen very soon. It's also your signal to push the button for the spaceship or squadron leader that's coming next. If you remember what's coming next, you should push the button as fast as you can once you see the signal. If you find that you don't remember what comes next, you may need to wait

until you see which spaceship actually appears. Even if you wait to see the spaceship, be sure to respond as quickly as you can. Regardless of when you respond, the spaceship or squadron leader will appear shortly after this signal comes on, and will remain on the screen until you've responded correctly. (If you've responded correctly before the spaceship or squadron leader appears, it will only come on very briefly.) If you make a mistake, the spaceship or squadron leader will not disappear until you press the correct button. Remember, though, to respond only <u>after</u> this signal has come on the screen. Remember, too, that only <u>one</u> spaceship or squadron leader follows each signal.

(The subject was shown each of the squadron leaders and spaceships in turn and taught their designations.)

Although you'll be responding with the middle button for either of the squadron leaders, the difference between them is important, because each squadron leader tells you that a particular patterned sequence is going to follow; if you learn these you'll always be able to predict correctly. Let's look at the first squadron leader again and I'll teach you the sequence of spaceships which always follows it.

(Squadron leader 1 is displayed and the subject is shown a sheet of paper which diagrams sequence 1.)

This shows you the order of the spaceships following the first squadron leader. Remember that the spaceships appear one at a time after each signal you'll see, so you'll never actually see groups of spaceships. The groupings of spaceships you see here are just so it will be easier for you to see the pattern in the sequence.

Let's go through the sequence together. As you see, this sequence will always begin with spaceship 1. You'll see one of spaceship 1, followed by one of spaceship 2. After you see one of each, that will repeat; you'll see one of spaceship 1 and one of spaceship 2 again. Once you've had one of each twice, the number of times you'll see each spaceship will increase. So, next you'll have two in a row of spaceship 1 and two of spaceship 2. After you've seen two of each, that will repeat, so you'll see two of spaceship 1 and two of spaceship 2 again. When you've had two of each twice, the repetitions will increase again, so you'll see three in a row of spaceship 1, followed by three of spaceship 2. Finally, that will repeat, so you'll see three of spaceship 1 and three of spaceship 2 again. After you've gone through the entire sequence, you can expect to see another squadron leader, which will tell you what the next sequence will be.

I'll give you a summary of this pattern which may help you remember it: After the first squadron leader,

starting with spaceship 1, you see one of each spaceship, twice; two of each spaceship, twice; and three of each spaceship, twice. OK?

Let's look at the second squadron leader again and we'll go over the sequence which always follows it.

(Squadron leader 2 is displayed. The subject is shown a sheet of paper which diagrams sequence 2.)

As you can see, this sequence always begins with spaceship 2. You'll see four in a row of spaceship 2, followed by four of spaceship 1. After you see four of each, the number of repetitions of each will decrease. You'll see three in a row of spaceship 2, followed by three of spaceship 1. Then the repetitions will decrease again, so you'll see two of spaceship 2, followed by two of spaceship 1. The number of repetitions will decrease one more time, so you'll see a squadron leader which will indicate which sequence comes next.

To summarize this pattern so that you'll remember it: After this second squadron leader, starting with spaceship 2, you see four of each spaceship, then three of each, then two of each, then one of each. OK?

As you can see, so long as you remember the sequences and where you are in a sequence, it's possible for you to press the correct button each time a signal appears. Remember that there's just one button for both

squadron leaders, so you don't need to know <u>which</u> squadron leader is coming in order to predict correctly, but only that it's time for a squadron leader to appear. Squadron leaders occur only at the beginning of each game (to tell you which sequence comes first) and then at the end of each sequence (to tell you which sequence follows). Is that clear?

(Subjects are shown the spaceships and squadron leaders again (in random order) and asked to identify each and give the appropriate response. This continues until subjects demonstrate that they are certain of the identities and response assignments of each. They are also asked to recite the pattern of spaceships following each squadron leader, again continuing until they are able to recite them without hesitation. Subjects are then shown the response signal and asked to identify it.)

As you read in the instructions, this signal may either appear here, in the lower half of the screen, or up here, in the upper half of the screen. There's no way of knowing in which location it will appear, so you'll have to look out for it coming on in either place in order to know when to respond. Wherever the signal appears, that's where the next spaceship or squadron leader will follow. You also have to be careful not to get ahead of the signal and respond too quickly if you know what's

coming, because the computer won't accept your response until after the signal appears. If you do respond too early, you'll find that the spaceship or squadron leader will just stay on the screen (as if you've made an error), and you'll have to respond again. Try to avoid responding before the signal, because it will actually slow you down in the game if you have to make extra responses. Also, the amount of time between when one spaceship disappears off the screen and when the next signal appears is going to vary, so sometimes you'll find you have to be ready very quickly, whereas other times you'll have plenty of time to know what's coming but will have to hold back so that you don't waste time responding before the signal appears. OK?

As the instructions said, you have an imaginary enemy in the game. This enemy is from time to time going to display things in the other half of the screen from where your signal is located. These will always be attempts by your enemy to throw you off what you're doing and will never be important, so you should try to ignore them and respond to your signal as quickly and accurately as you can.

Altogether, you're going to play 10 short games, each of which takes three or four minutes to play (although the first one you'll play may take longer since

you'll be getting used to the game). At the end of each game, you'll see your score for the game come up on the screen, and I'll come back into the room to see how you're doing. Remember, if you want to score well, you should try to be as fast and as accurate as you can be. Do you have any questions?

APPENDIX B

RESULTS OF ANALYSES OF VARIANCE

TABLE 10

ANALYSIS OF VARIANCE ON ERRORLESS TRIALS RTS
SEQUENCE 1

SV	df	MS	F	p
Block	4	29.077	87.89	.000
Error	172	.331		
Distraction	1	1.846	8.40	.006
Error	43	.220		
Unit Level	5	27.008	31.30	.000
Error	215	.863		
B x D	4	.463	2.40	.052
Error	172	.193		
B x U	20	1.783	6.29	.000
Error	860	.283		
D x U	5	.013	.08	.995
Error	215	.149		
B x D x U	20	.055	.28	.999
Error	829	.196		

TABLE 11

ANALYSIS OF VARIANCE ON ERRORLESS TRIALS RTS
SEQUENCE 2

SV	df	MS	F	p
Block	4	23.433	58.47	.000
Error	172	.401		
Distraction	1	.671	7.05	.011
Error	43	.095		
Unit Level	4	29.894	33.53	.000
Error	172	.892		
B x D	4	.080	.70	.591
Error	172	.114		
B x U	16	1.597	6.91	.000
Error	688	.231		
D x U	4	.150	1.52	.200
Error	172	.099		
B x D x U	16	.197	1.85	.022
Error	660	.106		

TABLE 12

ANALYSIS OF VARIANCE ON ALL TRIALS RTS
SEQUENCE 1

SV	df	MS	F	p
Block	4	54.246	66.06	.000
Error	172	.821		
Distraction	1	5.912	17.28	.000
Error	43	.342		
Unit Level	5	44.525	29.83	.000
Error	215	1.493		
B x D	4	1.713	4.95	.001
Error	172	.346		
B x U	20	4.593	7.69	.000
Error	860	.597		
D x U	5	.558	1.23	.295
Error	215	.453		
B x D x U	20	.399	.82	.691
Error	829	.487		

TABLE 13

ANALYSIS OF VARIANCE ON ALL TRIALS RTS
SEQUENCE 2

SV	df	MS	F	p
Block	4	43.725	75.28	.000
Error	172	.581		
Distraction	1	.255	.99	.326
Error	43	.258		
Unit Level	4	41.810	40.97	.000
Error	172	1.020		
B x D	4	.038	.15	.963
Error	172	.252		
B x U	16	3.377	11.12	.000
Error	688	.304		
D x U	4	.361	1.59	.178
Error	172	.226		
B x D x U	16	.172	.73	.765
Error	660	.235		

TABLE 14

ANALYSIS OF VARIANCE ON ERROR RATES
SEQUENCE 1

SV	df	MS	F	p
Block	4	.941	26.35	.000
Error	172	.036		
Distraction	1	.023	1.25	.269
Error	43	.018		
Unit Level	5	.909	21.57	.000
Error	215	.042		
B x D	4	.026	1.61	.174
Error	172	.016		
B x U	20	.063	3.51	.000
Error	860	.018		
D x U	5	.020	1.44	.212
Error	215	.014		
B x D x U	20	.018	1.13	.317
Error	829	.016		

TABLE 15

ANALYSIS OF VARIANCE ON ERROR RATES
SEQUENCE 2

SV	df	MS	F	p
Block	4	.858	35.65	.000
Error	172	.024		
Distraction	1	.027	1.71	.198
Error	43	.016		
Unit Level	4	.782	17.90	.000
Error	172	.044		
B x D	4	.015	1.28	.279
Error	172	.012		
B x U	16	.099	5.50	.000
Error	688	.018		
D x U	4	.043	4.00	.004
Error	172	.011		
B x D x U	16	.014	.98	.478
Error	660	.015		

APPENDIX C

RESULTS OF REGRESSION ANALYSES

TABLE 16

RESULTS OF TESTS OF INTERACTIONS TO PREDICT RT SEQUENCE 1

Interaction	R^2 Change	df	F
Trial Number x Distraction-now	.00097	4,40018	41.70
Trial Number x Distraction-past	.00000	4,40018	.07
Trial Number x ITI	.00252	4,40018	109.29
Trial Number x Unit Level	.00738	12,40010	68.02
Distraction-now x Distraction-past	.00001	4,40018	.21
Distraction-now x ITI	.00157	4,40018	65.44
Distraction-now x Unit Level	.00006	12,40010	.52
Distraction-past x ITI	.03130	4,40018	65.94
Distraction-past x Unit Level	.00019	12,40010	1.65

TABLE 16 - continued

Interaction	R^2 Change	df	F
ITI x Unit Level	.00152	12,40010	13.39
Trial Number x Distraction-now x Unit Level	.00058	24,39998	5.35
Trial Number x Distraction-past x Unit Level	.00089	24,39998	8.20
Trial Number x Error-past x Unit Level	.00468	24,39998	43.74
Trial Number x ITI x Unit Level	.00144	24,39998	13.46
Distraction-now x Distraction-past x Unit Level	.00035	24,39998	3.06
Distraction-now x ITI x Unit Level	.00010	24,39998	.89

TABLE 16 - continued

Interaction	R^2 Change	df	F
Distraction-past x ITI x Unit Level	.00103	24,39998	9.08

TABLE 17

RESULTS OF TESTS OF INTERACTIONS TO PREDICT RT
SEQUENCE 1

Interaction	R^2 Change	df	F
Trial Number x Distraction-now	.00373	4,34031	143.48
Trial Number x Distraction-past	.00038	4,34031	14.56
Trial Number x ITI	.00084	4,34031	32.44
Trial Number x Unit Level	.02042	10,34025	222.16
Distraction-now x Distraction-past	.00003	4,34031	1.17
Distraction-now x Unit Level	.00006	10,34025	.61
Distraction-now x ITI	.00033	4,34031	12.49
Distraction-past x Unit Level	.00038	10,34025	3.83
Distraction-past x ITI	.00007	4.34031	2.54

TABLE 17 - continued

Interaction	R^2 Change	df	F
ITI x Unit Level	.00055	10,34025	5.63
Trial Number x Distraction-now x Unit Level	.00019	20,34015	2.07
Trial Number x Distraction-past x Unit Level	.00040	20.34015	4.36
Trial Number x Error-past x Unit Level	.00071	20,34015	7.84
Trial Number x ITI x Unit Level	.00022	20,34015	2.44
Distraction-now x Distraction-past x Unit Level	.00017	20,34015	1.72
Distraction-now x ITI x Unit Level	.00013	20,34015	1.33

TABLE 17 - continued

Interaction	R^2 Change	df	F
Distraction-past x ITI x Unit Level	.00020	20,34015	2.05