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Selective Attention in Hyperactive Children Responsive to Methylphenidate

James Robert Allender

SELECTIVE ATTENTION IN HYPERACTIVE CHILDREN - ALLENDER

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SELECTIVE ATTENTION IN HYPERACTIVE CHILDREN RESPONSIVE TO METHYLPHENIDATE

BY

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B.A., Stanford University, 1975

THESIS

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SELECTIVE ATTENTION IN HYPERACTIVE CHILDREN RESPONSIVE TO METHYLPHENIDATE

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Electrophysiological measures of cortical activity have indicated that hyperactive children who show a positive response to methylphenidate may have a deficit in inhibitory innervation. It has been suggested that this deficit may occur in the sensory and motor systems and result in two major symptoms of hyperactivity, poor attention and excessive motor activity. In this experiment sensory inhibition was evaluated for hyperactive and normal subjects using a shadowing task with various types of distractors. It was hypothesized that if attentional deficits of hyperactive subjects were due to their inability to inhibit irrelevant sensory input, then shadowing performance for the hyperactive group should be equivalent to the performance of controls when no distractor was present, but inferior when speech was the distractor. In addition, it was hypothesized that methylphenidate should increase accuracy of shadowing performance for hyperactive subjects.

Errors of omission were used as the dependent measure. It was found that overall hyperactive subjects did more poorly than controls on shadowing letters under all three distractor conditions tests: no distractor, white noise, and speech. In addition, the interference during the three conditions was found to be different with speech being the most disruptive and white noise and no distractor being

equivalent. Neither the hypothesis of increased interference for hyperactive subjects with increased sensory input nor the hypothesis of improved performance with medication for the hyperactive children was supported. The lack of significance of these two tests must be qualified by the fact that a ceiling effect was found in the data. It was concluded that in this experiment hyperactive subjects demonstrated an attentional deficit when compared to normal subjects and that this deficit was not related to sensory input. However, conclusions cannot be made concerning the effect of medication or sensory input on hyperactive children's attention because of the ceiling effects in the data.

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An estimated 4-10% of elementary school children demonstrate symptoms indicating hyperactivity. These symptoms include: overactivity, inability to concentrate, and emotional explosiveness (Stewart, 1970). While these traits often appear together, there is no specific constellation of symptoms that uniquely defines the "hyperactive behavior syndrome." Many investigators have suggested that the lack of diagnostic criteria for hyperactivity has caused the label to be overused and applied to children with a variety of temperamental dysfunctions. The variability in responsiveness to amphetamines and other stimulant medications shown by these children seems to support this suggestion. Improvement of hyperactive symptoms with drug treatment does not occur in all hyperactive children, but in about 40-70%.

Satterfield (1974) found two subgroups of hyperactive children when he investigated the relationship between responsiveness to methylphenidate (Ritalin) and central nervous system arousal. Using EEG, skin conductivity, and auditory cortical evoked potentials, he found that hyperactive subjects who responded positively to methylphenidate were underaroused cortically compared to normal controls; hyperactive subjects who did not respond favorably to methylphenidate were judged already overaroused cortically compared to normal controls. Satterfield interpreted the inverse relationship between behavioral activity and brain arousal levels for the subjects who responded to

drug treatment as indicating a lack of cerebral inhibitory innervation, and speculated that this deficit was in the sensory and motor systems.

Several cognitive psychologists (most notably Broadbent, 1958; Treisman, 1960) have developed behavioral theories of selective attention that postulate the inhibition of sensory input. These theories are based primarily on data from experiments in which subjects were asked to repeat one message on a tape recording while ignoring a second, distracting message. The subjects' ability to report only general characteristics of the unattended message (Treisman, 1964) suggested a limited capacity, information processing system. Treisman agreed with Broadbent (1958) that selective attention acted to focus on information to be processed, since subjects seemed to select and store only one message in a fashion that allowed recall. Within this framework, the environment bombards the individual's sensory systems with more information than can be processed by his/her limited processing capacity. The limited channel capacity of the system necessitates the selection of some inputs and attenuation or suppression of other information from the environment. While the cognitive theorists may refer to this selection in behavioral terms, physiological psychologists also address the issue of selection of stimuli. A possible physiological mechanism for the selection and attention to relevant stimuli might be by the inhibition of neuronal activity in circuits mediating irrelevant input. If the activity in these circuits is inhibited, the likelihood of selecting or storing irrelevant stimuli would be lessened. Functionally, this would increase the probability that relevant stimuli would be selected and stored without interference from irrelevant sensory

input. Satterfield's speculation that hyperactive children lack sensory input inhibition on a neuronal level, therefore, fits well with clinical and experimental observations (Bryan, 1974) that these children are easily distracted in the classroom by extraneous stimuli.

The attentional experiments using hyperactive children have not clearly demonstrated a lack of sensory inhibition (in behavioral terms) for these children. In order to assess the possibility of impaired sensory selection or inhibition, an experiment would have to test a hyperactive child's distractibility while minimizing the importance of motor activity level and impulsive behavior. None of the experiments in the literature has done this. Lasky and Tobin (1973), for example, asked learning disabled subjects (a group that often exhibits hyperactive symptoms) to respond either orally or in writing to questions played over a speaker, while no distractor, or distractors of white noise or speech were played over other speakers. Their findings indicated that, relative to normal subjects, the learning disabled children showed greater interference from linguistic stimuli and that neither group's performance was compromised by white noise. While this task was relevant to classroom performance, the complexity of the task obscures the question of whether the learning disabled children were unable to inhibit sensory input. Campbell, Douglas, and Morgenstern (1971) found that hyperactive subjects responded more quickly and less accurately on a discrimination task compared to normal subjects. From this they concluded that hyperactive subjects were more impulsive and less reflective when attempting problem solving tasks. The question of distractibility is, therefore, confounded in the Laskey

and Tobin experiment, since difficulty on this task may be due to impulsive answering of questions rather than to distractibility. Along this line, the interaction of the type of distractor with the groups may only show that under greater stress the hyperactive children become even more impulsive.

Another study that examined distractibility in hyperactive children was reported by Sykes, Douglas, Weiss, and Minde (1971). These authors tested hyperactive and normal subjects on a continuous performance task. Subjects were instructed to push a button when an X was preceded by an A on a screen. Hyperactive subjects did more poorly than controls overall and white noise did not interfere with either group's performance. They also found that the performance of hyperactive subjects was improved by Ritalin. The major limitation of this study was that the only distractor they used was white noise. Because white noise is a nonmeaningful stimulus, the generalizability of this study is limited. Lasky and Tobin (1973) found no difference between white noise and quiet but did find a difference with a meaningful stimulus. This suggests that Sykes et al. (1971) also should have included this type of distractor.

Another line of attentional research has examined sustained attention in hyperactive children. Although this type of study does not address distractibility directly, it does pose related questions. Sykes, Douglas, and Morgenstern (1973) used four different tasks to assess sustained attention. These authors found that the reaction times of hyperactive and normal subjects were equivalent for a choice reaction time task. They concluded from this that hyperactive subjects [illegible] [illegible], [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] hypothesis concerning an [illegible] [illegible] in hyperactivity. [illegible]. The [illegible] of this type of design used with the [illegible], only [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] were more impulsive.

Another study that examined distractibility in hyperactive children was conducted by Cohen, Douglas, Weiss, and Minde (1972). These authors tested hyperactive and normal subjects on a continuous performance task. Subjects were instructed to push a button when an X was preceded by an A on a screen. Hyperactive subjects did more poorly than controls overall and white noise did not [illegible] either group's performance. They also found that the performance of hyperactive subjects was improved by Ritalin. The major limitation of this study was that the only distractor they used was white noise. Because white noise is a nonmeaningful stimulus, the generalizability of this study is limited. Camp and Zimet (1974) found no difference between white noise and quiet but did find a difference with a meaningful stimulus. This suggests that Cohen et al. (1972) also should have included this type of distractor.

Another line of attentional research has examined sustained attention in hyperactive children. Although this type of study does not address distractibility directly, it does have related implications. Sykes, Douglas, and Morgenstern (1973) used four different tasks to assess sustained attention. These authors found that the reaction times of hyperactive and normal subjects were equivalent for a simple reaction time task. They [illegible] [illegible] [illegible] [illegible] [illegible] were able to focus their attention normally for brief periods of time. The equivalence of reaction times for hyperactive and normal subjects seems surprising given that two other studies reported that hyperactive children show deficits in simple reaction time (Cohen, 1971; Dykman et al., 1974). This discrepancy may be due to the more complex demands in the task Sykes et al. (1973) reported. In their choice reaction time task a discrimination was required followed by a motor response. If hyperactive subjects decided more quickly, but reacted more slowly motorically, equivalent times might result for the two groups. This would be a reasonable possibility given the findings of Campbell et al. (1971). To substantiate this speculation, error rates should be examined, but the authors did not report these. In addition, without error rates the issue of distractibility is clouded since the degree of distraction caused by the irrelevant stimuli is not clear.

The three other tasks these authors used to assess sustained attention involved decision making over time. It is possible to explain group differences on these tasks by impulsivity in decision making, motor response deficits or attentional problems. On a task that required subjects to push buttons in response to lights, hyperactive subjects made more incorrect responses, false alarms, than normal subjects, but the two groups had the same number of correct responses. This seems to indicate that the hyperactive subjects were responding more frequently than normal subjects and so the differences in the groups may be based on a poorly modulated motor response system rather than an attentional deficit.

Two tasks that differentiated hyperactive from normal subjects were an auditory and visual form of the continuous performance task described above. In both of these tasks the hyperactive children made more incorrect and fewer correct responses. These results may be related to a combination of impulsive answering and motor overresponsiveness, since the authors reported that hyperactive subjects made more anticipatory and random errors. The issue of distractibility and interference by irrelevant stimuli, again is not clearly answered.

Another experimental task used to assess the attention of hyperactive children was the visual vigilance task reported by Anderson et al. (1974). These investigators required subjects to push a button after a specific stimulus combination (red-green light flash) and to ignore irrelevant stimuli (red-red or green-green flashes). They found a medication by age interaction indicating that medication aided their younger subjects (ages 6-8) but not the older subjects (ages 9-12). Any conclusions about sensory inhibition is not warranted from this experiment since the tasks did not vary the distractions presented to subjects. The physical orientation necessary in a visual task and the sustained position necessary in a vigilance task are both requirements that could be influenced by motor activity. This confounding obscures the system that is affected by the medication in this task for the younger subjects.

The present experiment attempted to assess selective attention in hyperactive children while avoiding the confounding factors presented in the experiment summarized above. To do this it is necessary to minimize motor requirements and the role that impulsive responses might

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The present experiment attempted to assess attention [illegible] in hyperactive children while [illegible] the [illegible] of the [illegible]. In [illegible] the [illegible].

play in the task, while maintaining the importance of sensory inhibition. A "shadowing task" similar to that first used by Cherry (1953) meets these requirements. In a shadowing task subjects are asked to repeat a message as they hear it, while ignoring simultaneous distracting auditory stimuli. Following Treisman's model of attention (1960), ignoring distracting auditory stimuli requires central sensory inhibition; presumably irrelevant input must be suppressed before reaching the limited capacity processor. The influence of responding without reflecting on items, which Campbell et al. (1971) found, should be minimized since the task requires oral repetition of auditory stimuli with minimal conceptual discrimination among them. In this case letters of the alphabet will serve as the relevant stimuli. Since the task is an auditory one, physical orientation is not necessary because stimuli can be delivered to a subject's ears by earphones. In this way motor activity should not influence arrival of stimuli.

Viewing a shadowing task as a measure of sensory input inhibition, one would hypothesize from Satterfield's (1974) work that nonmedicated hyperactive subjects who are responsive to methylphenidate would do more poorly than normals on such a task when distraction was present, but equivalently with no distraction. In addition, Satterfield's finding that response to medication was inversely related to cerebral arousal suggests that the effectiveness of methylphenidate may involve the amelioration of the inhibitory deficit. This, along with the clinical observations that medication often helps hyperactive children's behavior, suggests that hyperactive subjects should be able to perform better while taking medication than when not taking it. A final

hypothesis was derived from Laskey and Tobin (1973). These authors found that different types of distractors varied in their disruptive influence. The present study included different types of distractors (white noise, speech and no distractor) and so a difference among these distractors was predicted. Performance in the white noise and the no distractor conditions were expected to be equivalent for all subjects, and to differ significantly from the performance with the speech distractor.

Method

Subjects

Experimental subjects consisted of ten hyperactive boys drawn from patient files of Dr. George Brown, a pediatrician associated with Lovelace Clinic in Albuquerque, New Mexico. All experimental subjects had been diagnosed by Dr. Brown as having the hyperactive behavior syndrome and were known to have a positive clinical response to methylphenidate. They were between the ages of 9 years 1 month and 11 years 10 months, with a mean age of 10 years 7 months.

Control subjects were ten boys who were not hyperactive, drawn from the children and siblings of students enrolled in beginning psychology classes. The ages of the controls had the same mean and range as the ages of the hyperactive subjects. Each control subject was matched with an experimental subject so that he heard the same tapes, in the same ears and in the same order of distractors as his hyperactive counterpart.

All subjects passed a screening test for hearing.

Apparatus

An audiometer manufactured by Lafayette instruments was used to screen subjects' hearing. During the experimental task an Uher Royal De Luxe tape recorder with standard earphones was used to present the stimuli.

Stimuli

Six stereo tape recordings of six minutes' duration were used. On one track of each tape a female voice speaking letters of the alphabet (Y,L,I,G,R,U,F,O,K,Q) was recorded. These letters were presented approximately one every two seconds. For all six tapes this track was identical and served as the relevant stimuli. The other channel of each tape had (a) two minutes of quiet, (b) two minutes of white noise, and (c) two minutes of a man reading a children's story. These served as the distracting stimuli. Each of the six tapes had a different order of the three distracting stimuli (six possible orders), and the content of each distracting story was different (each tape having a unique story). There were sixty relevant stimuli during each of the two-minutes distractor segments.

Procedure

Subjects participated in two testing sessions of twenty minutes each. At the beginning of each session subjects were given a brief audiological screening test. This screening consisted of testing each ear with 25 db. tones at various frequencies between 500 and 8000 herz.

During the experimental task subjects sat behind a screen blocking their view of the equipment. They were asked to listen to one of the six tapes and repeat the letters they heard in one ear while ignoring the white noise or story they heard in the other ear. This task was likened to a pilot's attentional demands in an airplane, listening to a control tower while ignoring the engines and other people in the plane. The experimenter sat in the room and scored responses by hand notes. Omissions and incorrect identifications were scored as errors. Responses

also were recorded for scoring to determine scoring reliability. Relevant stimuli were presented at about 40 db. A and irrelevant stimuli at about 86 db. A.

After the first tape the same procedure was repeated with a second tape and with the relevant stimuli played into the subject's other ear. The ear that received the relevant stimuli first was counterbalanced between subjects, so that on the first testing session half of the subjects received the relevant stimuli in their left ear and half of the subjects received them in their right ear. This order was also counterbalanced within subjects so that if a subject received stimuli in his right ear first during his first testing, he received them in his left ear first during his second day of testing and vice versa.

Hyperactive subjects were tested while taking medication during one session and not taking medication during the other session. When subjects were tested in the no medication condition, they had taken no medication for a minimum of two days. Order of testing with and without medication was counterbalanced across subjects.

Design

This experiment was conceptualized as a five factor mixed design. Factor I: Ear into which the relevant stimuli were played was a within-subject factor with two levels--left and right. Factor II: Type of distractor was another within-subject factor having three levels--quiet, white noise, and speech. Factor III: Groups constituted a between-subjects factor having two levels--hyperactive and normal. Factor IV: Order of medication was a second between-subject factor included to evaluate if subjects who were first tested taking medication had an advantage over those not taking it at first testing. Factor V:

Medication usage was the third within-subject factor--no medication and usual dose of medication.

Control subjects were tested with no medication each time but their data were classified along this factor in accordance with the data of their matched counterpart. Although the medication factor did not reflect a real manipulation for the control subjects, they were classified along this dimension to establish a complete factorial design and to allow the order of medication to be a completely crossed factor and so assessed as a main effect. As a result, the main effect of medication was not meaningful in the analysis of variance performed on the combined data. The effect of medication on hyperactive children's attention was, therefore assessed by a simple main effect.

Results

Omissions and misidentifications were the two types of errors scored in the experiment. An omission occurred when subjects made no verbal response to a stimulus. Misidentifications were scored when incorrect verbalizations occurred in response to a stimulus. Interrater reliability was based on scores derived by the experimenter during a session and scores from a second rater listening to the tapes of subjects' responses. The correlation between raters was based on only eight hyperactive and eight normal subjects because of difficulty with the tape recordings. For omissions, the interrater reliabilities for the 24 cells of the design had a median of .973 and a range of .285 to 1.0. For misidentifications the interrater reliability had a median of .868 and a range of -.151 to .989. The lower reliability of the misidentifications seemed to be due in part to the poor quality of the tapes of the subjects' responses and the greater difficulty in distinguishing the incorrect verbalizations from the correct verbalizations. The analysis of the data was done only on the omissions because they proved to be a reliable measure while the misidentifications did not.

The multivariate approach to repeated measures was used for the analysis of the data (McCall & Applebaum, 1973). In this analysis none of the interactions was significant at the .05 level. There was a significant effect of the type of distractor with an $F(2, 15) = 5.1$,

$p < .02$. Out of a possible 60, the mean number of omissions for the different types of distractors were: quiet = .5; white noise = .97; and speech = 2.02. The mean number of omissions during quiet was not significantly different from the number of omissions during white noise, $\underline{F}(1, 16) = .041$, $p < .84$. The number of omissions during white noise was, however, significantly less than the number during speech, $\underline{F}(1, 16) = 4.5$, $\underline{p} < .049$. The group factor (i.e., hyperactive or control) produced a marginally significant main effect, with an $\underline{F}(1, 16) = 4.39$, $\underline{p} < .053$. The overall mean for hyperactive subjects was 1.5 omissions while the mean for normal subjects was .85 omissions, both out of a possible 60. Table 1 shows the mean number of omissions for the hyperactive and normal subjects at each level of distraction.

The effect of medication was examined by comparing hyperactive subjects while taking and not taking medication (normal subjects excluded from the analysis). This test was nonsignificant with an $\underline{F}(1, 8) = 1.4$, $\underline{p} < .27$.

The possibility that a ceiling effect influenced results is a concern, given the overall high level of performance. If the task was too easy for the subjects, it is possible that the high level of performance would cause differences to be missed. Two of the major hypotheses of this study were not supported and so the question arises whether there was really no effect for these tests or if a ceiling effect caused the effects to be obscured. For example, if the lack of a medication effect is examined by defining ceiling as less than two error per tape, five of the hyperactive subjects were at ceiling while taking medication and two were at ceiling when they were not

Table 1

Mean Number of Omissions of Hyperactive and Control Subjects during Each Type of Distractor

	Quiet	White Noise	Speech
Hyperactive Subjects	.75	1.03	2.63
Control Subjects	.2	.9	1.4

taking medication. Increasing task difficulty should then cause non-medication performance in the hyperactive subjects to change more than their performance while taking medication. Thus, increasing task difficulty might cause the medication versus no medication test to become significantly different.

Discussion

The results of this study did not support the major hypothesis that hyperactive subjects show greater interference by distracting auditory stimuli than controls. Because the mean number of omissions of hyperactive subjects paralleled omissions of the control across the three types of distractors, there is no reason to conclude that hyperactive children have a relatively greater problem ignoring irrelevant auditory stimuli. In other words, the lack of an interaction involving the types of distractors (quiet, white noise and story) and the group factor (hyperactive versus control) indicated that the effect of distractors was not greater for the hyperactive group. The lack of support for this hypothesis brings into question Satterfield's (1974) speculation that hyperactive children suffer from a lack of sensory input inhibition. It also suggests that the amount of stimulation in a classroom is not necessarily the factor that causes hyperactive children to have trouble paying attention. This conclusion, however, must be qualified because of the ceiling effect in the data. It is possible that the ceiling effect caused the interaction to be nonsignificant. The conclusions stated above would be more compelling if this experiment were replicated with increased task difficulty.

The overall difference between the hyperactive and normal subjects that was found must be attributed to other factors than sensory input, since there was no interaction between the group and distractor factors.

Deficits in either the selection of the appropriate message or in the vocal aspects of responses could have resulted in the overall group differences found. An example of an attentional problem that is not dependent on distraction can be postulated from Treisman's (1960) model of attention. She suggested that stimulus recognition was dependent upon input reaching a threshold of recognition that varied according to one's expectation of the stimulus. This recognition was important to attention since stimuli needed to be located in memory in order to be acted upon. If hyperactive subjects had less variability within their thresholds of recognition, it would result in poorer stimuli recognition and shadowing task performance. An explanation of the group differences involving output interference is also feasible. If the verbal output required in this experiment interfered with shadowing task more for the hyperactive subjects than for the control subjects, group differences would be expected. A final explanation for the group differences might be that the hyperactive subjects were not as motivated as the normal subjects and so expended less effort on the task.

The second hypothesis, postulating a positive medication effect on hyperactive subjects' performance was not supported. While it was hypothesized that methylphenidate would improve performance of the hyperactive subjects on the shadowing task, there was no significant difference found between their performance when taking or not taking medication. The lack of a medication effect on attention within this age group is consistent with the findings of Anderson et al. (1974). In this experiment the lack of a medication effect may have been due to a ceiling effect as already discussed. The nonsignificant results could

be due also to the fact that subjects were off medication for only two or three days prior to testing and that this is not a long enough period for the medication to wear off. Observations by parents of the subjects in this experiment do suggest that the medication wears off within approximately 12 hours, so that the period in this experiment was long enough.

Finally, the third hypothesis was supported by the main effect of the type of distractor. As was expected, quiet and white noise were equivalent as distractors while speech was the greatest distractor for both groups.

The findings of the present experiment suggest a line of research for the future. A replication of the present study with increased task difficulty seems important, since several conclusions were qualified by the presence of a ceiling effect. If groups differ with no interaction between group and type of distractor, as in the present study, the differences between the performances of hyperactive and normal subjects will need to be investigated. One cue that is within the relevant message that is important for shadowing performance is the contextual nature of the material. By varying the degree of context in the relevant message the importance of this cue for each group could be assessed. If it was found that context was less important for the performance of hyperactive subjects, it would explain the group differences in the present experiment. It would indicate that hearing a set of letters did not help the hyperactive subjects expect a letter as the next relevant stimulus and so facilitate their recognition of that stimulus.

If an interaction between distraction and groups is found in a replication of this study, it would lead to another line of research. In this case the importance of specific cues differentiating the relevant and irrelevant stimuli could be investigated. This investigation could be carried out by varying the specific cues that differentiate the two messages. The effectiveness of shadowing may improve for hyperactive children relative to normals as specific cues are dropped out. A relative difference in this direction would suggest that hyperactive children do not use certain cues as effectively as normal children. Based on these findings therapy programs might be developed to train hyperactive children to improve their selective attention.

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APPENDICES

Appendix I

Review of the Literature

Research involving the experimental task and research using hyperactive children are both relevant to the present study. This appendix will, therefore, be divided into sections. The first section will assume an historical approach to shadowing research and follow the development of various models of selective attention based on this experimental task. The other sections will then examine cognitive, motor, and attentional research with hyperactive children.

Theories of Attention

The term "shadowing" when used in psychological research refers to a procedure used to assess selective attention. In this task subjects are asked to repeat an auditory message as it is heard. Using this task, characteristics of selective attention may be evaluated by varying the nature of the shadowed message or by introducing simultaneous, competitive stimuli. Manipulations of location, meaningfulness and timing of the distracting stimuli have been examined and have led several cognitive psychologists (Broadbent, 1958; Deutsch & Deutsch, 1963; Treisman, 1960) to theoretical formulations of attention.

One of the earliest models of selective attention was introduced by Broadbent (1958). He viewed the nervous system as a single communication network with a limited capacity. He postulated a sensory store where sensory input is stored temporarily after entering the system.

From this store, information is selected to be processed. Sensory input is selected by a filtering process so that only a limited amount of information continues in the system. The selection of input to be processed is based on the drives of the organism at the time and on the characteristics of the stimuli, and so is considered nonrandom. The information not selected by the filter does not proceed further and is lost if not returned to the temporary store. If, however, it is returned to the temporary store, it can be selected the next time the selecting mechanism changes its focus. A final point which Broadbent included was that the switching of the stimuli selector requires time. The major point of Broadbent's theory which later theorists used was that attention selected information to be processed because the amount of information which can be processed at any one time is limited. The major criticism of his model was that he proposed that selection of information is based on the physical aspects of the stimuli.

While Broadbent's model accounted for the majority of published research at that time, research appeared in subsequent years that contradicted his model. Moray (1959) reported two experiments, the first being congruent with Broadbent's theory while the second was not. In the first he found, as earlier experimenters had, that subjects who shadowed a message played to one ear were able to report the content of the distracting message played into their other ear. Moray asked subjects to indicate whether specific words had been on either channel of the tape of which they had shadowed one channel. Subjects were shown three types of words: (1) words selected from the shadowed

message, (2) words which had been repeated 35 times on the unshadowed track, and (3) words rated as similar to the words of the attended message but which were not on either channel of the tape. Subjects were able to classify correctly words from the shadowed message, but responded similarly for words played to the unattended ears and for words played into neither ear.

This experiment suggested complete filtering of the unattended ear and was consistent with Broadbent's model. A second study reported in the same paper, however, contradicted his all-or-none filter. In the second experiment Moray asked subjects to shadow the message in one ear while in the unattended ear he played a distracting message which contained the subject's name. He found that a significant number of subjects heard their names which suggested that the unattended ear was not completely filtered out.

Another experiment by Moray and Taylor (1958) demonstrated the importance of context in shadowing a message, a variable not accounted for in Broadbent's model. The authors found that statistical approximations of speech sequences were more difficult (as indicated by error rates) to shadow than normal prose. They interpreted this finding as indicating that linguistic sequencing of words facilitated selective attention. While Broadbent mentioned that selection could be based on classes of words or physical features of words, he did not mention grammatical or semantic content as selection criteria. This study did not invalidate completely Broadbent's model, however, since increased shadowing accuracy could be due to improved guessing in the context condition.

Gray and Wedderburn (1960) demonstrated that subjects did not always group input according to the ear that it entered as Broadbent (1958) had reported. In the experiment three-word phrases were recorded on a tape so that words were delivered to alternate ears. Opposite each word on the other track of the tape a digit was recorded. Subjects were asked to report what they heard after each set of three pairings of a word with a digit. These researchers found that subjects used strategies of groupings based on ear of arrival and based on the meaning of the phrases. It was also reported that grouping by meaning was more efficient than grouping by ear. This finding contradicted Broadbent's model in that he had suggested that attending to one ear at a time was more efficient than switching between ears. He had postulated that grouping by ear to be more efficient because he considered each ear as a channel for input that could be attended to easily. A weakness in this study is that their conclusions are based on the lists that were recalled perfectly. One might argue that these lists were the ones which were easiest for the subjects and so did not demand selective attending.

Treisman (1960) investigated contextual effects on attention in more depth and suggested modifications of Broadbent's model to accommodate new experimental data. In her experiments she asked subjects to shadow a logically sequenced message played into one ear and to ignore a comparable message played into the other ear. In the middle of the task the two messages were switched to the opposite ears. This switch in messages required the subject to shift attention suddenly to a different message. Treisman scored the number of words

the subject repeated from the wrong ear. She found a significantly greater number of intrusions from the wrong ear during the five words immediately after the switch of messages than during any other part of the tape. She interpreted this finding as indicating the importance of the contextual cues in shadowing, which supported the conclusions of Moray and Taylor (1958). Her findings also indicated that subjects were not completely filtering out the distracting stimuli on the basis of ear since they shadowed words from the ear that was not to be attended to.

In this same paper and others (Treisman, 1964a,b) Treisman suggested two major modifications of Broadbent's model. The first modification proposed that the filter which blocked sensory input in Broadbent's model, merely attentuated sensory input. By an attentuating filter Treisman meant that the unselected messages were not completely blocked, but were weakened in strength. This postulated filter attenuated input selected on sensory features; then these weakened signals of the unattended messages plus the unaltered signals of the attended message continued within the information processing system. The next step in this model involved input recognition.

Treisman postulated that in order for input to be processed it needed to be recognized and that recognition of linguistic input depended on stimuli surpassing certain thresholds of recognition. These hypothetical thresholds of word recognition were named dictionary units. The value of a dictionary unit was unique for every word and depended on an initial level of the threshold for the word, as well as the subjects' expectation of the word's appearance. Within Treisman's [illegible] reported [illegible] the whole [illegible]. [illegible] [illegible] from the [illegible] [illegible] [illegible] [illegible] of the [illegible]. The [illegible] [illegible] of the [illegible] [illegible] [illegible] [illegible] [illegible] and [illegible] (19[illegible]). The [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

In this same paper and others (Postman, 19[illegible]) [illegible] [illegible] [illegible] [illegible] [illegible]. [illegible] [illegible] that the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] way [illegible] [illegible] [illegible] [illegible] [illegible].

Thorndike [illegible] that [illegible] of a [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] of the [illegible] [illegible] the [illegible] of [illegible] [illegible] [illegible] [illegible] of the [illegible] [illegible].

model, these dictionary units determined the selection of linguistic stimuli to be processed since some stimuli reached threshold and were recognized and others did not reach threshold and were therefore lost.

These modifications allowed Treisman's model to explain both the facilitating effects that context produced in the shadowed message and also the subjects' recognition of their names in the unattended message. Because dictionary units could be lowered by an individual's expectation of a word, a word placed in a meaningful context would be more easily recognized than a word outside a meaningful context.

Thus, subjects were able to shadow meaningful speech better than statistical approximations of speech presumably because expectations of words would be greater if they occurred in meaningful context. The fact that subjects recognized their names in unattended messages may be explained by postulating that an individual's name has a lower initial dictionary unit. One would then expect a subject to recognize his/her name even when the input was attenuated.

An alternative model of selective attention which does not postulate a perceptual filter was proposed by Deutsch and Deutsch (1963). The limited capacity of the attentional system in their theory was attributed to the limited response capabilities of an organism. In their model all incoming stimuli were perceived and processed to the point of the initiation of a response. After being equally processed, but prior to the initiation of a response, different inputs were postulated to have different levels of importance to the organism. The organism, unable to respond to all input, selected the

most important input to which to respond. This selection of one response over others involves the blockage of the less important responses by the action taken on the most important stimuli. An important point is that they defined a response in broad terms including any processing from covert rehearsal of an item to a motor act.

These authors supported their model with much of the same evidence which Treisman had used to support her model. They felt that complete perceptual analysis of all input was indicated by some of the factors which influenced performance on shadowing tasks. Two examples they used were: (1) the importance of context in messages being shadowed, and (2) the increased distractibility of messages as their meaning approached the meaning of the shadowed message.

Comparisons are often made between the Treisman model and the Deutsch and Deutsch model of selective attention. One of the most significant distinctions between the theories is the point in the attentional system where the bottleneck occurs. For Treisman this bottleneck occurs during the recognition of stimuli. Before reaching the recognition phase of perception, all incoming stimuli were equally processed (although some inputs were attenuating). At the recognition phase only a limited number of the inputs surpass their recognition thresholds and are processed further. For Deutsch and Deutsch the bottleneck in the attentional system is in the selection of a response. Until this point in their model all stimuli are processed equally. In the selection of the response some stimuli are acted upon and others are not.

In spite of the differences between these two models of attention, they both postulate the inhibition of certain stimuli in favor of other

stimuli. Treisman's model of attention specifies inhibition within the attenuating filter. This becomes clear if inhibition is thought of as the stopping or slowing of electrical activity in one nerve cell by activity in another cell. Her speculation that the physiological signals of unattended stimuli are weakened while the signals of attended stimuli are not weakened fits well with a concept of neuronal inhibition. In this case the attended stimuli causes the weakening of the unattended stimuli. If sensory input is selectively impeded, the model must postulate inhibition of certain neurons by other neurons.

The locus of inhibition in the model of Deutsch and Deutsch is in the behavioral responses. After all inputs are registered and evaluated, the one with the most importance is acted upon to the exclusion of the other inputs. In one paper (Deutsch & Deutsch, 1967), this exclusion was explicitly talked about as one response inhibiting the others.

The inhibition in each of the models can be explained in neuronal terms. On a cellular level there are basically two types of neurological circuits that produce inhibition of one neuron's activity by another neuron's activity. The most easily understood inhibitory circuit is one in which one neuron hyperpolarizes another. This hyperpolarization causes the voltage across the membrane of the recipient cell to be lowered. This increase in electrical potential of the cell decreases the probability of the neuron firing, because the activation of a neuron is achieved through the depolarization (or decreased negative potential) of its membrane. Therefore, increasing membrane potential of one neuron in a sequence of neurons decreased the probability that the cellular chain will become electrically active. This type of

inhibition is analogous to increasing the weight of one domino in a chain so that it is more difficult to push over, and therefore, decreasing the probability that later dominoes will be pushed over.

The second type of inhibition is analogous to decreasing the weight of one domino in the chain so that it has less power to push over the next. This is another way to lower the probability that later dominoes will fall. Neurologically this type of inhibition results from one neuron (A) decreasing the amount of transmitter emitted by another neuron (B) through depolarization of its membrane potential. In this way the second neuron's influence (B) on a third neuron (C) is decreased. This circuitry decreases the likelihood that one neuron (C) fires as the result of activity in another neuron (B). It is, therefore, considered that the first neuron in the series (A) inhibits the last neuron in the series (C) indirectly through another neuron (B). Either of the two models of selective attention presented could be based on either type of inhibition.

After discussing inhibition and two models of selective attention that involve the concept, it seems appropriate to mention Norman's model of attention in which inhibition does not play a central role. Norman (1968) proposed a model of attention that combined features of both Treisman's and Deutsch and Deutsch's models. From Treisman's model he used the idea of adjustable activation levels and from Deutsch and Deutsch's model he adopted the idea that all input has access to memory. In this model incoming information is processed and some representation of it is stored in memory. This location in storage produces what he called sensory activation. This activation combines

with activation from the individual's expectation for each incoming stimulus (pertinence activation) and results in a total level of activation for each stimulus. The stimulus with the strongest activation level is then selected to be acted upon. In this model attention influences processing by increasing the expectation of a certain item. This increased expectation yields increased activation and so facilitates an item's processing. Thus, the model emphasizes facilitation rather than inhibition.

Having discussed the theoretical literature concerning selective attention, research reports on hyperactive children and attention will now be examined. The review starts with Satterfield's (1974) suggestion that there are deficits of neurologic inhibitory systems in hyperactive children. This is relevant to models of attention since so many of them involve inhibition as a concept. Research investigations of cognitive styles and motor activity levels of hyperactive children will be presented because these factors might influence performance on attentional tasks. Finally, the literature on hyperactivity and attention will be reviewed.

Hyperactivity and Cortical Inhibition

Many models of selective attention involve the concept of inhibition which makes the work of James Satterfield relevant to the attentional deficits attributed to hyperactive children. Satterfield (1974) found two subgroups of hyperactive children when he investigated the relationship between responsiveness to methylphenidate (Ritalin) and central nervous system arousal. Using EEG, skin conductivity, and auditory

evoked potentials as measures of cortical activity, he found that hyperactive subjects who responded positively to methylphenidate were underaroused cortically compared to normal controls. In addition, hyperactive subjects who were not responsive to methylphenidate were overaroused cortically compared to normal controls. He interpreted the inverse relationship between behavioral activity levels and brain activity levels for the subjects who responded favorably to drug treatment as indicating a lack of cortical inhibitory innervation and speculated that this deficit was in both the sensory and motor systems.

While Satterfield interpreted his data as indicating a possible deficit in sensory inhibition, attentional experiments have not clearly demonstrated a lack of sensory inhibition (in behavioral terms) in hyperactive children. Conclusions concerning sensory inhibition cannot be made from the experimental tasks reported because they have not tested hyperactive children's attention in a fashion that controls for activity level or impulsive behavior, while maintaining the importance of sensory inhibition.

There is evidence of differences in cognitive styles between hyperactive and normal children; therefore, tasks in which cognitive style is important cannot address attentional issues without confoundings. Similarly, studies utilizing attentional tasks which are influenced by motor activity are confounded due to the differences in motor activity levels between hyperactive and normal children.

Hyperactivity and Impulsive Behavior

Campbell, Douglas, and Morgenstern (1971) looked at cognitive styles in hyperactive subjects. These authors felt that learning deficits

of these children could be clarified by investigating the basic strategies they used in problem solving. They examined four different dimensions of cognitive style for their subjects while taking or not taking methylphenidate. One dimension that they studied was "reflection-impulsivity." They felt this dimension was reflected by speed of decision making and they measured it by the speed and number of errors on a matching task. Secondly, they studied "field dependence and independence" on the Children's Embedded Figure Test, which is considered a measure of the integration of a target with its background. A third dimension, "automization," was measured by timing a subject on a simple repetitive task, naming colors on a page. The authors felt this indicated a person's ability to perform an overlearned task and to resist distraction. The fourth dimension they investigated was "constricted-flexible control." This was a measure of distractibility in which irrelevant and contradictory material was added to the color naming task to assess the amount of interference it caused.

The major finding of this study was that hyperactive subjects were more impulsive than the normal controls. They responded more quickly and made significantly more errors than normals on the matching task. They were also more "field dependent" than normal controls. The authors demonstrated that the cognitive impulsivity of the hyperactive children was decreased by methylphenidate, while their field dependence was not changed with the drug.

Kagen et al. (1964) demonstrated that impulsivity on a decision making task was accompanied by decreased performance in normal children. Another study indicating that impulsive behavior decreased performance

measure changes in location. The time a subject was engaged in one activity was also measured. They interpreted the differences between groups as indicating that the short attention span of the hyperactive subjects caused them to shift their attention readily so that they moved around the room more than the controls.

Reaction time and fingertapping are two other aspects of motor behavior which have been looked at in hyperactive children. Dykman et al. (1972) discussed research which indicated that Minimal Brain Dysfunction (a label used for any hyperactive children) children have deficits in both these tasks. Hyperactive children were slower on repeated fingertapping as well as on a simple reaction time task. Their impairment on both of these tasks may, however, be due to attentional problems rather than motor dysfunction.

Attentional Research

Just as there is difficulty in examining motor activity without the influence of attention, there is difficulty in examining attention without the influence of motor activity. In addition, attentional research with hyperactive children is often confounded with impulsive behavior due to the task demands. For example, Lasky and Tobin (1973) asked learning disabled subjects (a group that often exhibits hyperactive symptoms) to respond either orally or in writing to questions played over a loud speaker, while no distractor, or distractors of white noise or speech were played over other speakers. Their findings indicated that, relative to normal subjects, the learning disabled children showed greater interference from linguistic stimuli and that neither group's performance was compromised by white noise. While this

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tional problems rather than motor dysfunction.

<u>Attentional Deficits</u>

[illegible] the influence of attention, there is difficulty in assessing attention without the influence of other variables. In addition, [illegible] concerned with hyperactive children are often confounded with [illegible] due to the task demands. For example, [illegible]

[illegible]

task was relevant to classroom performance, the complexity of the task obscures the question of whether the learning disabled children had attentional problems. Campbell, Douglas, and Morgenstern (1971) found that hyperactive subjects responded more quickly and less accurately on a discrimination task compared to normal subjects. From this they concluded that hyperactive subjects were more impulsive and less reflective when attempting problem solving tasks. The question of distractibility is, therefore, confounded in the Lasky and Tobin experiment, since difficulty on this task may be due to impulsive answering of questions rather than to distractibility. Along this line, the interaction of the type of distractor with the groups may show only that under greater stress the hyperactive children become even more impulsive.

Another study that examined distractibility in hyperactive children was reported by Sykes, Douglas, Weiss, and Minde (1971). These authors tested hyperactive and normal subjects on a continuous performance task. Subjects were instructed to push a button when an X was preceded by an A on a screen. Hyperactive subjects did more poorly than controls overall and white noise did not interfere with either group's performance. They also found that the performance of hyperactive subjects was improved by Ritalin. The major limitation of this study was that the only distractor they used was white noise. Because white noise is a nonmeaningful stimulus, the generalizability of this study is limited. Lasky and Tobin (1973) found no difference between white noise and quiet but did find a difference with a meaningful stimulus. This suggests that Sykes et al. (1971) also should have included this type of distractor.

Another line of attentional research has examined sustained attention in hyperactive children rather than distractibility. Sykes, Douglas, and Morgenstern (1973) used four different tasks to assess sustained attention. These authors found that the reaction times of hyperactive and normal subjects were equivalent for a choice reaction time task. They concluded from this that hyperactive subjects were able to focus their attention normally for brief periods of time. The equivalence of reaction times for hyperactive and normal subjects seems surprising given that two other studies reported that hyperactive children show deficits in simple reaction time (Cohen, 1971; Dykman et al., 1974). This discrepancy may be due to the more complex demands in the task Sykes et al. (1973) reported. In their choice reaction time task a discrimination was required followed by a motor response. If hyperactive subjects decided more quickly, but reacted more slowly motorically, equivalent times might result for the two groups. This would be a reasonable possibility given the findings of Campbell et al. (1971). To substantiate this speculation, error rates should be examined, but the authors did not report these. In addition, without error rates the issue of distractibility is clouded since the degree of distraction caused by the irrelevant stimuli is not clear.

The three other tasks these authors used to assess sustained attention involved decision making over time. It is possible to explain group differences on these tasks by impulsivity in decision making, motor response deficits or attentional problems. On a task that required subjects to push buttons in response to lights,

hyperactive subjects made more incorrect responses, false alarms, than normal subjects, but the two groups had the same number of correct responses. This seems to indicate that the hyperactive subjects were responding more frequently than normal subjects and so the differences in the groups may be based on a poorly modulated motor response system rather than an attentional deficit.

Two tasks that differentiated hyperactive from normal subjects were an auditory and visual form of the continuous performance task described above. In both of these tasks the hyperactive children made more incorrect and fewer correct responses. These results may be related to a combination of impulsive answering and motor over-responsiveness, since the authors reported that hyperactive subjects made more anticipatory and random errors. The issue of attention and interference by irrelevant stimuli, again is not clearly answered.

Another experimental task used to assess the attention of hyperactive children was the visual vigilance task reported by Anderson et al. (1974). These investigators required subjects to push a button after a specific stimulus combination (red-green light flash) and to ignore irrelevant stimuli (red-red or green-green flashes). They found a medication by age interaction indicating that medication aided their younger subjects (ages 6-8) but not the older subjects (ages 9-12). The physical orientation necessary in a visual task and the sustained position necessary in a vigilance task are both requirements that could be influenced by motor activity. This confounding obscures the system that is effected by the medication in this task for the younger subjects.

Another type of experimental task used to assess the distractibility of learning disabled subjects presents irrelevant information with relevant information, then later asks subjects to recall both types of information. Hallahan (1974) asked subjects to remember the serial order of cards with pictures of animals and foods on each card. He emphasized in his instructions to order the animals. The authors found that on this measure, which they considered a measure of distractibility, learning disabled children made more errors than controls. Performance on this task was correlated with field dependence, a cognitive style. The connection between cognitive style and this measure of distractibility seems to lessen the impact of this study in respect to attention, because it confounds the issue of distractibility with field dependence.

This same issue surfaced when Hallahan (1974) interpreted the results of Koegh and Donlon (1972) in terms of distractibility. Koegh and Donlon reported that learning disabled subjects were influenced more by the background on a rod and frame test than normal subjects. This test usually is interpreted as a measure of cognitive style (field dependence versus independence). But the method again raised the problem of distinguishing between distractibility in terms of attention and distractibility in terms of cognitive style.

A distinction that may clarify the difference might be that distraction impinges upon perception but field dependence occurs during encoding or a more central stage of cognitive processing. If this distinction could be tested experimentally, the relationship between cognitive style and attention could be evaluated. It could, therefore,

be decided if these two factors, distraction during attentional tasks and cognitive style, were independent or highly correlated. If this distinction were made, the deficits that hyperactive children show could be clarified.

The literature dealing with hyperactive children and attention suffers several difficulties. First, the diagnostic criteria of the hyperactive behavior syndrome vary between studies. Different studies use labels like MBD, learning disabled or hyperactive as if they were clear diagnostic categories. The intersection among the various categories means that studies may or may not be using comparable subjects. In addition, Satterfield's (1974) finding that hyperactive subjects seem to form at least two subgroups according to brain activity, suggests that within the labels there are different dysfunctions. A second difficulty of this literature is the confounding of tasks that tap more skills than the experimenters may recognize as factors in the testing. The tasks often ask children to organize and execute complex skills which involve abilities on which hyperactive or learning impaired children are impaired. A final problem is the variety of measurement techniques that are not cross validated but are assumed to measure the same or comparable characteristics. In conclusion, the conceptual confusion of the literature on hyperactive children makes it difficult to draw a clear picture of the attentional processes in the syndrome from the experimental research.

Appendix I

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Appendix II-A

Table 2

Order of Relevant Stimuli*

1.	Y	I	Q	I	G	U
2.	L	I	Y	U	R	U
3.	I	L	L	O	R	K
4.	P	U	Q	I	F	F
5.	Y	O	P	Q	G	L
6.	I	L	U	I	U	I
7.	L	K	I	I	Y	R
8.	Q	Y	O	R	F	F
9.	K	O	F	U	L	O
10.	G	F	F	G	K	U
11.	F	F	T	U	I	Q
12.	Y	L	I	Q	U	Y
13.	Q	Q	C	O	R	G
14.	Q	G	R	K	U	R
15.	F	Y	L	U	O	L
16.	K	G	Y	O	Y	O
17.	Q	U	U	Y	O	L
18.	G	Y	O	L	I	U
19.	I	O	R	F	K	Q
20.	I	K	L	Q	L	Q
21.	F	I	O	O	F	Q
22.	Q	G	I	L	K	Y
23.	O	Q	U	Y	O	L
24.	Y	F	F	U	I	U
25.	K	R	K	K	K	I
26.	K	K	R	Y	K	G
27.	Y	Y	F	O	O	K
28.	F	U	F	U	G	L
29.	O	L	U	O	Y	I
30.	R	L	O	U	L	R

*Each column constitutes one minute of stimuli.

Appendix II-B

Order of Distractors on Tapes

Tape 1 - Quiet, White Noise, Speech

Tape 2 - Quiet, Speech, White Noise

Tape 3 - Speech, White Noise, Quiet

Tape 4 - Speech, Quiet, White Noise

Tape 5 - White Noise, Quiet, Speech

Tape 6 - White Noise, Speech, Quiet

Appendix II-C

Table 3

Tapes Played to Subjects during Each Testing Session

Subject	Time 1		Time 2	
No.**	Left Ear	Right Ear	Left Ear	Right Ear
1	1	3*	2*	4
2	5	1*	6*	2
3	2*	4	1	3*
4	4*	6	5	1*
5	3*	5	6	2*
6	6	2*	1*	3
7	4	6*	3*	5
8	2	4*	5*	1
9	1*	3	4	6*
10	5*	1	2	4

*Tape played first at the session

**Subjects 1 through 4 were taking medication at Time 1. Subjects 5 thought 10 were not taking medication at Time 1.

Appendix II- D

Instructions to the Subject

What I'm going to ask you to do is put these earphones on and listen to part of this tape recording. In one ear you will hear a woman saying some of the letters of the alphabet. In the other ear sometimes it will be quiet, sometimes you will hear a crackly noise like static and sometimes you will hear a man reading a story. Your job is to listen to the woman saying the letters and say each of the letters right after she does. I want you to ignore any sounds in your other ears. This will tell me how well you can pay attention to what the woman says and ignore other sounds. This is like a pilot in an airplane who listens to a control tower and has to ignore the sound of the engine and other people talking. So remember right after the woman says a letter I want you to say it. The letters will be coming quickly so you have to pay close attention. After you say each letter, I will mark it down. Any questions?

Appendix III-A

Table 4

Number of Omissions for Each Subject

	Taking Medication						Not Taking Medication					
	Left Ear			Right Ear			Left Ear			Right Ear		
Subject No.*	Quiet	White Noise	Story	Quiet	White Noise	Story	Quiet	White Noise	Story	Quiet	White Noise	Story
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	2	0	1	0
3	0	0	0	0	0	0	0	1	2	0	0	3
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	10	11	0	0	0	0	0	0
6	0	0	1	0	0	0	0	0	2	0	0	1
7	0	0	1	0	1	0	0	0	1	0	0	0
8	0	1	3	1	0	0	0	0	0	3	0	0
9	0	0	0	0	0	0	0	3	0	0	0	0
10	0	0	0	0	0	1	0	1	0	0	0	0
11	6	7	0	0	2	3	0	0	2	2	0	21
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	1	0	3	1	0	3	1
14	6	5	2	1	4	0	7	0	9	0	0	3
15	0	1	13	0	1	5	1	1	9	0	0	3
16	0	0	0	0	0	1	0	2	0	0	0	0
17	0	0	1	0	0	0	0	0	0	0	0	1
18	0	2	1	0	0	0	0	1	0	0	0	1
19	0	1	0	0	0	2	0	1	1	0	0	2
20	0	0	0	0	0	1	4	7	26	3	0	5

*Subjects 1-10 are the control subjects.
Subjects 11-20 are the hyperactive subjects.

Appendix III-B

Table 5

Analysis of Variance Source Table

Sources	df	MS	F
Between effects:			
Diagnosis	1	6.407	4.386*
Order of Testing	1	.03	.04
0 x D	1	1.097	.751
Error	16	1.461	
Within effects:			
Medication	1	48.4	.74
0 x M	1	94.7	1.45
D x M	1	102.5	1.57
0 x D x M	1	.57	.009
Error	16	65.17	
Ear	1	39.99	.76
E x 0	1	34.42	.65
E x D	1	115.58	2.19
0 x D x E	1	25.34	.481
Error	16	52.73	
E x M	1	9.8	.297
E x M x 0	1	9.45	.286
E x M x D	1	3.2	.097
E x M x 0 x D	1	19.727	.597
Error	16	33.02	.597

*$p < .053$.

Appendix III-B

Table 6

Multivariate Analysis of Variance Source Table*

Sources	S	M	N	ϴ
Within effects:				
Type of Distractor	1.0	0.0	6.5	.405**
0 x T	1.0	0.0	6.5	.245
D x T	1.0	0.0	6.5	.150
0 x D x T	1.0	0.0	6.5	.017
Within effects:				
M x T	1.0	0.0	6.5	.152
M x T x 0	1.0	0.0	6.5	.135
M x T x D	1.0	0.0	6.5	.157
M x T x 0 x D	1.0	0.0	6.5	.250
E x T	1.0	0.0	6.5	.001
E x T x 0	1.0	0.0	6.5	.109
E x T x D	1.0	0.0	6.5	.007
E x T x 0 x D	1.0	0.0	6.5	.105
E x T x M	1.0	0.0	6.5	.190
E x T x M x 0	1.0	0.0	6.5	.082
E x T x M x D	1.0	0.0	6.5	.047
E x T x M x 0 x D	1.0	0.0	6.5	.153

* In the Multivariate Approach to repeated measures all within effects with more than one degree of freedom are analyzed with multivariate analysis of variance.

** $p < .02$.

Appendix III-C

Table 7

Interrater Relibiability Correlations for Each Cell of the Design for the Omission Data

	Off Medication						Taking Medication					
	Left Ear			Right Ear			Left Ear			Right Ear		
	Quiet	White Noise	Story	Quiet	White Noise	Story	Quiet	White Noise	Story	Quiet	White Noise	Story
Controls	*	.866	.974	*	1.0	1.0	*	1.0	.917	.667	.977	1.0
Hyper-active	.969	.701	.947	*	.633	.285	.944	.997	.997	1.0	.972	1.0

*A correlation could not be calculated because one or both judges had the same value for all subjects.