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ABSTRACT

A conceptual framework of attention can be organized around three functions of attention: determining how much capacity is to be deployed (attention allocation), for how long (attention maintenance), and to which potential information sources (attention direction). Within this framework, several critical distinctions can be made between processes that have previously been treated as unitary. For example, attention maintenance can be distinguished from attention allocation since attention maintenance is not a passive continuation of an initial allocation of attention to task, but rather it is an active sustained processing that keeps capacity deployed. Additional distinctions can be made between sustained processing and avoidance of distraction and within the area of distraction. This leads to the concept of age-appropriate distractibility, which encompasses a description of avoidance of distraction performance in terms of interaction between task variables, such as type of distractor, and child characteristics, such as developmental level. A review of the literature on children's attention within this framework can identify several areas where needed information is not available. In particular, little is known about children's task analysis and monitoring abilities in all areas of attention capacity development. The investigation of component processes of attention in special children should enable the diagnosis of attention problems by functional categories, such as sustained processing or avoidance of distraction deficits, rather than the current, less analytic diagnostic categories, such as hyperactivity and learning disability. (HOD)

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Technical Report No. 256

AN ANALYSIS OF CHILDREN'S AVOIDANCE OF DISTRACTION WITHIN A FRAMEWORK OF ATTENTION PROCESSES

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An Analysis of Children's Avoidance of Distraction within a Framework of Attention Processes

There is a large body of literature concerned with the role of attention in children's learning and problem solving. This literature contains many reports of the critical role of attention, and the lack of sufficient attention is considered to be one of the primary causes of learning and problem solving deficiencies. Deficient attention has become a global descriptor for a diverse set of problems. In fact, attention deficiency is used as one of the main criteria in the definitions of retarded, hyperactive, minimal brain dysfunction, and learning disabled children. In this literature attention is generally treated as a monolithic process, one not subject to further analysis.

A very different view of attention is found in the literature on adult cognitive processing. Attention is viewed as a set of processes that control the deployment of information processing resources. That is, attention is analyzed into component processes. However, the research within this view has not generally addressed learning and problem solving tasks, being for the most part limited to tasks such as signal detection, scanning, and shadowing. Nor has this component process view been much applied to issues of attention development and disability.

In this paper, we will argue that there are benefits to be gained from extending the component process view of attention. We will present a framework of attention processes which provides a basis for organizing and interpreting the existing findings on attention in learning and problem solving tasks for both normal and special children. The framework draws heavily from previous work in: (a) cognitive psychology, in particular

Kahneman's (1973) capacity-oriented model of attention processes; (b) educational psychology and special education, especially Keogh and Margolis' (1976) classification of attention disabilities exhibited by children in learning situations; and (c) developmental psychology, mainly the work on metacognition by Flavell, Brown, and their respective associates (Brown, 1976, 1977; Brown & DeLoache, 1978; Flavell, Freidricks, & Hoyt, 1970; Kreutzer, Leonard, & Flavell, 1975). Each of these areas provides a unique input while contributing to a consistent general framework of attention processes.

The view of attention underlying our framework stems from cognitive psychology. Attention is viewed as an integral part of information processing, more specifically that part which controls the deployment of information processing capacity. It is assumed that this capacity is limited, and that the total amount of information available generally exceeds it. Therefore, the effective deployment of capacity is essential for successful learning, problem solving, or performance in almost any task (see Broadbent, 1971, 1977; Kahneman, 1973). Furthermore, attention is viewed as a system of qualitatively distinct, but interrelated processes. One aim of this paper is to provide an analysis of this system, and to demonstrate that this analysis can provide an overall framework into which findings about individual parts of the system can be integrated.

Attention determines the deployment of information processing capacity along three dimensions, how much capacity is deployed, for how long, and to which information sources. Our framework is organized around these three functions of attention, which we label attention allocation, attention maintenance, and attention direction, respectively. The operation of each function involves three processes: (a) analyzing the task demands; (b) deploying capacity; and (c) monitoring the appropriateness of the capacity deployed. Table 1 presents an overview of the three functions of attention and the three types of processes in the framework.

Insert Table 1 about here.

Attention allocation is a matter of intensity, of how much processing capacity is to be deployed to a given task.[1] Following Kahneman (1973), it is assumed that the amount of attention capacity available can vary over time and tasks. Mental effort is the process that determines the amount of capacity available for allocation to learning and problem solving tasks. Appropriate allocation of attention requires analyzing the task to be performed in order to judge how much attention it will require, allocating the attention capacity, and then monitoring whether the amount allocated is appropriate. If allocation is found to be appropriate, the attention maintenance processes come into play. If allocation is found to be inappropriate, the attention allocation processes are applied again.

The function of attention direction is to determine where information processing capacity is to be deployed. Attention direction involves making choices. The attender must continuously choose which of the potential sources of information are relevant to the given task. The attender must also avoid directing attention to irrelevant information. That is, attention direction encompasses both selectivity and avoidance of distraction. Appropriate direction of attention requires analyzing the task to determine criteria that can be used to distinguish relevant from irrelevant information sources; then directing attention to only the relevant sources, and subsequently monitoring the effectiveness of the attention direction. If attention is found to be directed effectively, the attention maintenance processes come into play. If it is found to be directed ineffectively, the processes of task analysis and deploying attention to particular sources are applied again.

Directing attention to relevant sources has been associated with both filtering and selecting processes. The direction of attention as filtering (found in models such as Broadbent's, 1958, 1971, 1977) refers to a reduction of information occurring automatically at a perceptual or very early stage of processing. The direction of attention referred to as selectivity involves a longer duration, later occurring process of continually using discrimination criteria. Pick, Frankel, and Hess (1975) regard selectivity as a decision making ability under cognitive control. Brown (1977) discusses "rules, strategies and operations which can be used to make more efficient use of a limited capacity system." Some of these rules, strategies, and operations are involved in selecting a subset of the available information for further processing, i.e., selectivity. Since we are concerned with learning and problem solving tasks, selecting, but not filtering, will be considered under attention direction.

Attention maintenance is a matter of duration, of how long attention capacities are to be deployed to a given task and, within a task, to each source of information. Appropriate attention maintenance requires analyzing the task to determine the duration of attention necessary to complete it, sustaining processing for that duration, and monitoring progress toward task completion. Maintenance also depends upon the appropriateness of the prior allocation and direction of attention.

In most attention research, a central assumption has been that the ability to sustain processing on a particular task results in the effective avoidance of distraction, and conversely, the successful avoidance of distraction results in sustained on-task processing. In most investigations with adults and older normal children, the data support this assumption of equivalence between sustained processing and avoidance of distraction. However, research with very young children and some special children presents an important body of data that challenges this equivalence assumption. Sykes (1969; Sykes, Douglas, & Morgenstern, 1973) presents evidence that hyperactive children have difficulty in sustaining processing of relevant information sources. If these difficulties are a function of an inability to avoid distraction, then one could expect to find evidence that hyperactive children are readily distractible. Douglas and Peters (in press) report several attempts to demonstrate problems of distractibility in hyperactive children (e.g., Campbell, Douglas, & Morgenstern, 1971; Cohen, Weiss, & Minde, 1972; Peters, 1977; Sykes, 1969). These studies have shown hyperactives to be no more distractible than their normal agemates. Additional evidence of this nature comes from studies of normal and retarded children by Ellis, Hawkins, and Jones (1963). Their study required sustained attention to a task with and without experimentally introduced distractors. While their measures indicated poorer sustained processing performance for retarded than for normal children, they also indicated that experimental distraction did not differentially affect the two groups.

response latencies and GSR amplitudes as quickly as adults (i.e., allocate attention as efficiently), but were unable to maintain these optimal levels over longer trial intervals (i.e., did not sustain processing as well).

Related evidence for sustained processing as being distinct from allocation processes is found in the Zelniker, Jeffrey, Ault, and Parsons (1972) work with impulsive and reflective children. When the preparatory interval of a reaction time task was less than 20 seconds, response latency data did not distinguish the two groups of children. The impulsives appeared to be as able to effectively attend to the reaction time set as were the reflective children. However, when the preparatory interval was longer than 20 seconds, increasing the sustained processing demands of the task, response latency was significantly longer for the impulsive children. These results indicate an inability of these children to sufficiently sustain processing, although they were able to initially allocate sufficient attention to the task. These results are consistent with clinical reports about hyperactive children who begin tasks well but soon go off task. In the framework presented here, such children would be considered to have attention maintenance problems but not attention allocation problems.

In the following three sections, children's abilities and difficulties in attention allocation, maintenance, and direction will be discussed. For some of the processes, there is very little information available. There have been very few studies of children's skills at the task analysis and monitoring processes involved in attention. Therefore, we will have little to say about these areas. There is also a lack of information about children's abilities to alter mental effort in attention allocation and so the section on attention allocation will be brief. The information available response latencies and GSR amplitudes as quickly as adults (i.e., allocate attention as efficiently), but were unable to maintain these optimal levels over longer trial intervals (i.e., did not sustain processing as well).

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There is also a great deal of information available about children's abilities to avoid distraction. However, reviews of this research do not present the same general agreement as found in reviews of children's attention maintenance abilities. In fact, reviewers of this literature generally point out that the research does not yield consistent findings, and that very little can be concluded (Hallahan & Reeve, in press; Tarver & Hallahan, 1974). In the section on attention direction, we will consider the research on avoidance of distraction in detail, and present an analysis of types of distractions that resolves the apparent inconsistencies in this literature.

Attention Allocation

As mentioned earlier, the amount of capacity available for processing is a result of the amount of mental effort extended (Kahneman, 1973). Optimal effort creates the maximal available capacity, while extreme levels of effort result in diminished available capacity. Thus in addition to judging task demands, allocating the appropriate amount of attention to a task involves the ability to extend varying levels of effort and the ability to monitor the match between the effort extended and the effort judged as appropriate. Generally the performance of children has been described in terms of whether or not the effort extended has been appropriate for the task, not in terms of the range of effort of which they are capable, and not in terms of their ability to change effort in response to task demands.

Hafter and Johnson (Note 1) demonstrated that adults can control the amount of attention capacity allocated to a task. They measured effort as the rate of responding on a self-paced task. Subjects who performed the task for three minutes expended greater effort than that expended during the first three minutes of performance by subjects who thought they would be performing the task for one hour. In a similar study these same investigators found that adults would alter pacing in response to changes in reward schedules within the task. Hafter and Johnson conclude that adults were very capable of self-pacing in order to conserve available capacities and maximize payoffs.

Unfortunately there have been no similar investigations with children to determine whether they have comparable control over their own allocation of attention capacities. Investigations that examine children's ability to pace their effort to match task demands are needed to determine the development of such an ability. However, there is some indirect evidence available on children's inhibition of other activities, such as motor activity, which may compete for needed attention capacity.

Maccoby, Dowley, Hagen, and Degerman (1975) found the ability to inhibit motor activity during key periods of a problem solving task was characteristic of the more successful problem solvers in a group of normal preschoolers. Harrison and Nadelman (1972) also found the ability to inhibit motor movement was positively correlated with response latency and negatively correlated with errors in black preschool children. Tarver and Hallahan (1974) note that hyperactive behavior is often cited as a main problem of learning disabled children. They suggest that some of these children do not allocate appropriate capacity to meet task demands because they are unable to control excessive motor behavior. Sykes, et al. (1973) and Sykes, Douglas, Weiss, and Minde (1971) examined reaction time performance in hyperactive and normal children. When the experimenter provided the child with a warning before each trial and withheld presentation of the target stimuli until the child's attention was directed to the screen on which the stimuli were presented, hyperactive children's performance was as good as normal children's. That is, waiting to present stimuli to hyperactives until after they had limited motor activity and visually oriented to the screen appeared to compensate for their own inability to do so on cue, a problem in allocating attention to the task.

The general pattern of results from these studies seems to indicate that groups of children who show poor problem solving abilities due to difficulty in attention allocation also exhibit high overall levels of motor behavior. Many studies have examined the effectiveness of training programs designed to decrease excessive motor activity (e.g., Allen, Henke, Harris, Baer, & Reynolds, 1969; Doubrous & Daniels, 1966; Meichenbaum & Goodman, 1971; Patterson, 1965). These programs have met with mixed success. Douglas (1972) reports that in some cases improved performance of hyperactives was actually accompanied by increased frequency and amplitude of irrelevant motor responses. These results are not necessarily opposed to the earlier conclusions. In all cases, those subjects whose performance was adequate or improved demonstrated the ability to alter their motor behavior as the task demands changed.

Children's abilities to analyze task demands have been studied mainly in the area of memory development. Brown (1976, 1977; Brown & DeLoache, 1978) describes a set of processes critical in adapting memory performance to task requirements. She discusses finding that young children who can accurately choose the most effective study method (e.g., naming, sorting, rehearsal) for a given task do not necessarily use the method they choose when required to actually perform the same memory task. Even children who demonstrate the ability to use a given study method effectively when explicitly instructed to do so often fail to use an effective method when not given explicit instructions.

The behavioral descriptions of clinicians, teachers, and some researchers indicate that some of the problems children demonstrate in attention demanding tasks are analogous to the problems described by Brown for memory task performance. That is, some children who are able to allocate an appropriate amount of capacity when capacity demands are made explicit fail to adapt capacity spontaneously to suit the task demands. While there have been a few investigations of attention comparable to the memory work of Brown, there is insufficient information to determine whether children with attention allocation problems fail to judge correctly the amount of capacity needed for a particular task, or whether they are capable of making the initial judgment but then fail to allocate the amount of attention judged to be appropriate.

Recent work with academically normal children by Miller and Bigi (in press) examined first-, third-, and fifth-grade children's awareness of task demands. As part of the study, children were asked to construct easy and hard visual search tasks for other children of their grade and to rate the difficulty of experimenter-constructed tasks. While the accuracy of ratings and the proficiency of constructing differentially difficult tasks increased with grade level, even the youngest children made fairly accurate judgments. The authors interpreted their findings as evidence for an early development of the awareness of task demands and the awareness that these demands could affect one's performance. Humphrey (1982) investigated kindergarten, second-, and fourth-grade children's abilities to judge attention demands from descriptions of various tasks with and without added distractions. Accuracy of judgments comparing nondistraction and distraction tasks increased significantly with grade level. However, even the kindergarten children judged the distraction tasks as more difficult and requiring more attention than the nondistraction tasks.

These studies represent initial investigations of children's awareness of attention demands of various tasks. They provide evidence that at least by early grade school, children are capable of assessing the relative attention capacity demands of tasks. However, they still do not tell us whether these same children spontaneously make such judgments when faced with attention demanding tasks, and whether making such judgments actually leads to self-initiated changes in capacity deployment to meet perceived task demands. These questions await further research.

Attention Maintenance

The research on children's abilities to sustain processing has generally used either vigilance or reaction time tasks. The reader is referred to extensive reviews and analyses of these data by Alabiso (1972), Douglas (1972, 1974), Krupski (in press), and Tarver and Hallahan (1974). However, it should be noted that the attention maintenance processes required in these tasks differ from those required in learning and problem solving tasks. Learning and problem solving typically require more complex task analyses to determine the appropriate duration of attention. They also generally require sustaining attention to more sources of information than vigilance or reaction time tasks. Also, learning and problem solving often involve interrupting sustained processing in order to redirect attention as the task progresses.

As a result of these differences between the two types of tasks, the reaction time and vigilance studies do not provide information about the task analysis and monitoring processes of attention maintenance. These processes may play an important role in learning and problem solving. However, they have not been dealt with in previous models of attention processes and little is known about children's awareness of the need to perform these processes in attention demanding tasks, their competency at these abilities when explicitly instructed to perform them, or their spontaneous performance of these processes. The literature on attention problems contains some reports of difficulties in attention maintenance, such as premature response determination (impulsivity), and over persistence and rigidity of attention. However, these reports are limited to descriptions of poor performance on tasks requiring attention maintenance.

There are no data available from direct investigations of task analysis or monitoring abilities required for attention maintenance in learning and problem solving. Extrapolating from Brown's work with similar skills in memory development, it might be expected that these abilities would demonstrate a pattern of development from abilities involving decisions about external and more concrete information (task goals) to decisions about internally determined but observable information (performance progress) to decisions about internal and less readily identifiable information (input from interactions with other decisions about allocation and direction of attention). This development could also be expected to interact with the development of the ability to sustain processing itself.

Attention Direction

Selectivity and avoidance of distraction represent two conceptualizations of attention direction. Selectivity refers to the ongoing processing of relevant or target information, while avoidance of distraction refers to the continuous restriction from processing of irrelevant or nontarget information. A common set of criteria define the target and nontarget information for both purposes. Selectivity and avoidance of distraction can be viewed as analogous to the successes and errors of a task performance. They reciprocally indicate the operation of the same process, but provide different information about it. Therefore investigations of selectivity and investigations of avoidance of distraction are both relevant to attention direction. The reader is referred to a review by Pick et al. (1975) on the development of selectivity in children. Their work will be supplemented here with a discussion of the data on children's ability to avoid distraction and the problems exhibited by distractible or nonselective children. Following this, we will briefly discuss children's abilities to analyze the attention direction demands of a task, and to monitor their own attention direction.

Avoidance of Distraction

The avoidance of distraction literature contains a large and unwieldy body of data. Tarver and Hallahan (1974), in their review of this literature, note the difficulty in generalizing across studies. They find the results dependent "upon the investigator's concept of distractibility and the resulting measures employed." In this section, we will present a review of these studies organized according to types of distraction, defined by the criteria necessary to discriminate the relevant information from the potential distractors. This organization enables a coherent review of the literature that should facilitate the evaluation of children's abilities to direct attention.

As used in this paper, the term distraction refers to information that is irrelevant to performing the given task and that can compete with relevant information for processing capacity. In addition, the term distraction is reserved for stimulus information that need not be processed at all during the task.[2] A distraction effect is said to occur when the presence of such irrelevant or nontarget information causes a disruption or decrement in the processing of the relevant or target information, and in subsequent task performance.

This definition implies that a particular experimental design is required to assess distraction effects. As both Peters (1977) and Humphrey (1978) have noted, measurement of distraction effects entails assessing performance differences between a nondistraction condition and a directly comparable distraction condition. It is not sufficient to compare two or more groups on one distraction task without consideration of the relative nondistraction task performances of these groups. Studies by Doyle (1973), Norber and Norber (1975), Peters (1977), Sabatino and Ysseldyke (1972), and Stainback, Stainback, and Hallahan (1973) illustrate this point. These investigations all found poorer distraction task performance for the special children examined relative to the normal controls. However, these special children also exhibited poorer performance on the nondistraction tasks, and therefore did not demonstrate any differential performance decrement due to the introduction of distractors. Without the benefit of a nondistraction performance baseline measure, very different and erroneous conclusions could have been reached.

A second design specification made by Peters (1977) is that the order of the nondistraction and distraction tasks be counterbalanced. This becomes particularly relevant when assessing distraction effects in children who might have difficulties in maintaining attention that would lead to performance decrements on the second task administered independent of any distraction effects.

Distractibility has been cited as a characteristic of many populations of children. However, as mentioned earlier, the investigations of distractibility have not yielded findings that generalize across studies. There are several reasons for the inconsistencies in results. These reasons relate to critical distinctions that have often been neglected in investigations of the causes of distraction. First, an implicit assumption in much of this research has been that all distraction conditions present the same, unspecified type of processing interference. This has lead to a second questionable assumption, that the effects of the distractors are additive such that the use of multiple distractors is assumed to cause increases in this same type of unspecified processing interference.

Not all distraction conditions present equivalent amounts and types of processing interference. There is a need for a finer distinction among the stimuli labeled as distraction to distinguish the kinds of information each presents and the information processing demands associated with each. To clarify some of the ambiguity and apparent conflicts in the results of previous studies of distraction in normal and distractible children, the many examples of distractors found in the literature can be described in terms of the following classes.

External stimuli (ES) are independent of the task and supply no task-relevant information (e.g., lights, buzzers, white noise, and environmental surroundings). Internal stimuli (IS) are part of the task materials or context, but irrelevant to the task or redundant with task-relevant information and therefore not necessary for task performance (e.g., borders, illustrations, and nonrelevant physical features of task stimuli).

Within the class of IS distractors, several finer distinctions can be made. The differences in attention direction demands in terms of the processing capacity required to employ a single discrimination criterion throughout the performance of a task versus the capacity required to employ multiple discrimination criteria reflects a meaningful difference within IS distraction. Although not directly discussed, one should be aware that differences among the discrimination criteria themselves (e.g., saliency, frequency) may also be useful distinctions for classifying IS distraction.

However, the consideration of these other distinctions is beyond the scope of this paper. The distinctions made among IS distractors will be limited to two general classes: (a) simple-internal stimuli (SIS) that can be readily distinguished from target stimuli on the basis of simple criteria, that is, criteria specifying single dimensions or category differences (e.g., "all red items are distractors," "only animal pictures are important"); (b) complex-internal stimuli (CIS) that are distinguished from target stimuli by compound criteria, that is, the simultaneous use of two or more dimensions or category differences (e.g., "only animal pictures in green borders are important").

Additional sources of related information, not usually employed as experimental distractors but often found in classroom situations, are temporarily defined stimuli (TDS). They contain information that is temporarily of no use to task performance, but will become relevant after a time delay or some initial processing of target information is completed. TDS may be external or internal, but are distinguished from target stimuli by temporal criteria linked to task progress.

Insert Table 2 about here.

These categories of distraction, summarized in Table 2, represent general groupings on a continuum of stimuli, but they are not arbitrary groupings. Other reviews have also made attempts to organize the distraction literature by grouping studies into categories of distractors employed. However, the bases of these groupings have reflected stimulus characteristics independent of the demands placed upon the subject, such as sensory modality categories (cf., Alabiso, 1972; Hallahan & Reeve, in press).

Categorizing distraction into such groups as auditory and visual distractors may serve to reduce memory load, but, as these reviewers themselves note, it does not reveal any consistency or generality across studies within each group. In the subsequent discussions, it will be shown that categorizing distraction studies in terms of the cognitive demands placed on the subject by the presence of the distractor yields a consistency across studies that reveals particular developmental trends in the ability to avoid distraction.

In their review, Hallahan and Reeve (in press) classify distraction studies by modality of the distractor, but within modalities they discuss the relative effects of "proximal" and "distal" distractors. This distinction has the same basic character as the external-internal distinction, but it does not make as clear a distinction nor explain the distinction in terms of information processing demand differences. Rosenthal and Allen (1978) have also noted a distinction among task information sources that parallels the external-internal distinction made here, but these authors do not investigate distinctions within internal information sources, nor have they considered TDS as a class of distraction. Thus the classification of distractor stimuli presented here uses distinctions consistent with some of those in previous reviews, while enabling a more coherent organization of the distraction literature. The following reanalysis of the results of frequently cited distraction studies in terms of the above classes of distractors reveals consistent within-class effects of distraction.

External stimulus distraction. ES distractors present information external to the task at hand. They are often physically separate from the task materials themselves and in some cases are of a different sensory modality than the target information. These differences provide a number of highly salient stimulus dimensions that distinguish ES information from target information. Of the classes of distraction sources discussed in this paper, ES distractors are the most readily discriminable. It could be expected that as a child develops an awareness of information differences and the need to process information selectively, ES information would be the first class of distractors to be successfully discriminated from target information. A re-examination of investigations employing ES distractors supports this hypothesis and provides some indication of the approximate age level at which normal children begin to avoid ES distraction.

Perhaps the best example of research employing ES distractors is Turnure's (1970, 1971, 1977) work. He used mirrors, placed so the subjects could view themselves, as distractors during simple learning tasks. From these studies and earlier work (Turnure & Zigler, 1964), Turnure proposed the concepts of outer-directed and inner-directed problem solving or attention strategies. He described the behavior of those children for whom mirrors were disruptive stimuli as outer-directed. Their glances to the mirror were viewed as part of attempts to gain more information to help with task performance. An inner-directed strategy described those children who restricted their scanning and information processing to the task materials, and therefore were not hindered by the presence of ES distractors.

Within Turnure's concepts of outer- and inner-directed attention strategies is the distinction between external and internal information, that is, between irrelevant and task-relevant information. Thus one interpretation of some children's poor performance in the presence of ES distractors is that those with outer-directed attention strategies do not sufficiently discriminate ES from task information. There is some evidence to support this hypothesis.

Turnure's (1970) study of 5½- to 7½-year-olds noted that mirror distraction produced significant performance decrements for only the youngest children. Turnure (1971) also examined the effects of ES distraction on the performance of preschool children (3.3 to 4.9 years old) and again found only the youngest children were susceptible to distraction effects. However, Turnure cautions that this particular sample of children was from a university preschool and very advanced, and therefore their performance might be more comparable to that of an older age group.

An initial conclusion from Turnure's findings would be that prior to about 5 years of age, children are not capable of making discriminations between task and nontask information sources. However, the work of Keogh, Welles, and Weiss (1972) suggests that this conclusion might underestimate younger children's abilities. They found that task difficulty was an important variable in whether 4- and 5-year-olds exhibited off-task glancing, i.e., an outer-directed attention strategy. When children performed a simple cancellation task, no significant off-task glancing behavior was shown, but performance of an ambiguous puzzle task was accompanied by a great deal of off-task glancing. Clearly these children were capable of avoiding ES distraction under some performance conditions, but failed to use these discrimination abilities in the difficult task. Gelman (1978) noted task difficulty and task familiarity as very important determinants of whether preschool children demonstrate particular advanced cognitive skills or appear to lack them completely.

It appears from these and other studies employing ES distraction (see Douglas, 1974) that children older than early grade school age spontaneously discriminate ES from task information and are not disrupted by the presence of these distractors. However, while some preschool children may be capable of making external-internal information source discriminations, they may fail to use such discriminations spontaneously to direct their attention if the central task is difficult. Preschoolers and some special populations of children appear to adopt an outer-directed attention strategy that allows ES distractors to disrupt performance. The failure to employ spontaneously the appropriate and available discriminations of information will be discussed further with the processes of task analysis and monitoring.

Internal stimuli distraction. The external-internal dimension distinguishes ES from other information sources. Both SIS and CIS information sources are internal to the task at hand. They are information contained within the task materials but not required for task performance. SIS information is discriminated from target information by single physical dimensions or defining category distinctions. CIS information requires compound criteria, that is, the identification of two or more dimensions or categories, to discriminate it from target information.

The distinction between SIS and CIS information sources may appear to be very subtle, but a comparison of investigations employing SIS information and those employing CIS information as distractors reveals distinct differences in specific groups' abilities to avoid distractions. Pick et al. (1975) review several studies on children's memory for relevant (target) and incidental (distractor) information. They do not make a distinction between those tasks employing SIS incidental information and those employing CIS incidental information. However, they do note important variables that determine whether children separate task information sources or perceive them together (e.g., spatial separation between information sources, class membership differences). These variables are consistent with the distinctions between SIS and CIS information sources.

An area of research that deals with a related distinction is the work on integral and nonintegral dimensions of stimuli (Garner, 1970; 1974). Integral dimensions are those perceived as single features of the stimulus (e.g., hue and brightness), while nonintegral dimensions are perceived as separable features (e.g., size and hue). Garner (1970) points out that whether a dimension is integral or nonintegral can vary with different subjects. Shepp and Swartz (1976) have demonstrated a developmental trend in the perception of the integrality of dimensions. In particular, they found that some dimensions perceived as nonintegral by fourth-grade children were perceived as integral by first-grade children. They conclude that "with increasing amounts of perceptual learning, the child would be expected to extract dimensions of the stimulus input, with the results that perceived differences between integral and nonintegral dimension would emerge."

In order to select relevant information and avoid distraction by irrelevant information, the dimensions distinguishing relevant from irrelevant must be perceived as nonintegral. Thus, the ability to discriminate IS from relevant information is dependent upon the ability to perceive the nonintegral dimensions of the stimulus. A child who could not do so would suffer from IS distraction. Since the ability to perceive the nonintegrality of dimensions increases with age, we would expect the ability to discriminate IS from relevant information to show a similar development.

The ability to discriminate SIS information requires a single nonintegral dimension criterion. Discriminating CIS from relevant information requires what Garner refers to as "perceiving the dimensional structure" of the nonintegral dimensions. This refers to the perception of multiple nonintegral dimensions and the co-occurrence of particular values of these dimensions within a single stimulus. Therefore, the ability to discriminate SIS information should develop before the ability to discriminate CIS information.

The developmental hypotheses derived from the Shepp and Swartz (1976) data are given further support from a study by Doyle (1979). Doyle examined 8-, 11-, and 14-year-old boys' performance in a study of auditory SIS distraction during a central-incidental learning task. In the nondistraction conditions, children heard a female voice reading target words. In the distraction conditions a male voice simultaneously read distractor words. Doyle's study is particularly relevant for several reasons: (a) It contained both distraction and nondistraction conditions, affording a within subject measure of the effect of distraction on task performance; (b) the study assessed the degree of intrusion of distractor words during a simple verbal repetition of the target words performed at the time of stimulus presentation (a measure analogous to glance behavior during visual presentations of target-nontarget displays); and (c) the use of a recognition test of both target and distractor words (used as foils in multiple-choice items) avoided the differential time strain on memory that occurs when incidental recall follows target recall.

There were three main findings in Doyle's experiment. First, the youngest children had a disproportionately greater number of errors from intrusions of distractor words while attempting to repeat the target words. This suggests problems in the initial discrimination of target from distractor information. Second, only the youngest children demonstrated negative correlations of target word retention with distractor word retention, the trade-off often referred to in central-incidental studies. Finally, an age by condition interaction indicated a performance difference between nondistraction and distraction conditions that was significant for 8-year-olds, but not for 14-year-olds. These results indicate that the youngest children were unable to discriminate initially between the target information and the SIS distractors during stimulus presentation, were non-selective in the processing of the target and distractor words, and showed a performance decrement in the presence of SIS distractors. However, none of these points could be concluded from the data of the 14-year-olds. The 11-year-old children exhibited intermediate performance which was closest to the 14-year-olds' data.

The results of the Doyle (1973) and Shepp and Swartz (1976) studies suggest that a second- and third-grade age group would still fail to demonstrate abilities to discriminate SIS from target information reliably and to employ this discrimination spontaneously to direct attention selectively. Results from the Shepp and Swartz (1976) study also imply that beginning sometime around fourth grade, children's knowledge of non-integral dimensions and the emerging awareness of the nonintegral dimensional structures would allow them to perform compound criteria discriminations necessary to distinguish SIS from target information and to begin to distinguish CIS from target information. Experimental evidence to support this latter hypothesis is indirect.

In most investigations specifically designed to demonstrate distraction effects, ES or SIS distractors have generally been employed. Those studies in which CIS distraction is used are typically concept identification studies (e.g., Eimas, 1969; Gholson & Danziger, 1975; Gholson & McConville, 1974) or embeddedness tasks (e.g., Campbell, Douglas, & Morgenstern, 1971; Elkind, Larson, & Van Doornick, 1965; Sabatino & Ysseldyke, 1972). These studies demonstrate performance differences between groups of children who are assumed to differ on particular cognitive abilities, including distractibility. Conclusions drawn from performance differences on these tasks refer to the sources of distraction inherent in the task materials (CIS) that may be responsible for the poor performance of distractible children (e.g., impulsives, field-dependent children, learning disabled, hyperactive, and developmentally young) relative to their normal controls.

Thus, although the concept identification and embeddedness studies were not distraction investigations, differences in distractibility and selective attention to irrelevant stimulus dimensions are used as explanations of group performance differences. Essentially, embeddedness tasks require the identification of a target stimulus, and concept identification tasks require the identification of the concept or criteria that define the target stimuli. Solution of both tasks requires that subjects be able to discriminate target stimuli using criteria that specify particular values on two or more dimensions (e.g., "green squares," "straight lines that form right triangles"). Errors on both tasks reflect attention to distractors (i.e., the field, or the wrong stimulus dimensions) that results from either an inability to discriminate stimuli by compound dimension values, or failure to use such discriminations to direct further attention processing selectively.

While variable task difficulty and the use of different test forms obscures exact correspondence across studies, the general results of studies employing concept identification and embeddedness tasks indicate that those normal children exhibiting adequate task performance are middle to late grade school age. It should be noted that ease of perception of non-integrality of dimensions can be expected to vary with the particular stimulus dimension involved, and therefore the development of the ability to perceive relevant dimensions as nonintegral would also vary with the particular dimensions involved. The studies and learning tasks discussed here generally deal with simple physical features of stimuli such as color, shape, and size. As a result, their general findings point to consistent ages associated with the development of abilities to deal with SIS and CIS discriminations. These developmental conclusions may not hold for tasks or learning situations in which different, less salient dimensions form the discrimination criteria for relevant information.

A more direct assessment of children's abilities to discriminate and avoid distraction from CIS information requires an investigation of performance on a task under both nondistraction and CIS distraction conditions. Data from this type of design is necessary to test the hypothesis that children at or beyond the fourth-grade level can discriminate CIS distractors and avoid target information processing interference in the presence of these distractors.

Temporarily defined sources. The final class of distractor to be discussed is TDS distraction. As mentioned earlier, TDS information is discriminated from target information by temporal criteria linked to task progress or time delays. The effect of TDS distraction on children's performance has not been experimentally investigated. Reports from teachers and clinicians and some post hoc explanations of experimental results have claimed that TDS distraction has caused particular performance decrements. It has been suggested that time cues are particularly difficult criteria (relative to physical features) for young and special populations of children (e.g., Piaget, 1971). There is evidence that self-monitoring of task progress is also a difficult process for some children (see Brown, 1977). Since TDS information is defined by temporal and task progress criteria dimensions, qualitatively different from the physical criteria defining ES, SIS, and CIS information, TDS information might therefore be particularly difficult to discriminate from target information and could be expected to be a very potent source of distraction. However, the effect of TDS information attention direction is as yet highly speculative.

Differences between TDS and other types of distracting information have been confounded with other factors. While other sources of distraction need not be specifically pointed out to the child, and generally are not, TDS are singled out as information that will be relevant at some later time and thus may be made particularly salient to the child. Also, the status of ES, SIS, and CIS information does not change, while the status of TDS information is explicitly expected to change. In some tasks this requires the child to self-monitor his/her progress within the task and to re-assess the status of the TDS information at a later time, processes that could be expected to add considerable complexity and difficulty to the task.

Summary of distraction classifications. The above discussion of ES, SIS, CIS, and TDS distraction leads to particular hypotheses about an interaction of discrimination abilities (assumed to be closely linked to age and school experience) and the types of distractors. Imposing the classification of distraction reveals consistent within-class distraction effects. While each distraction type or class requires qualitatively different information discriminations, the types of distractors can be roughly rank ordered according to the ages at which they no longer lead to significant disruptions of task performance, that is ES, SIS, CIS, and TDS, from earliest to latest mastered.

Humphrey (1982) investigated the abilities of kindergarten, second-, and fourth-grade children to avoid ES, SIS, and CIS distractors during a learning task. Within-subject performance differences for a learning task given under counterbalanced nondistraction and distraction conditions revealed main effects of grade and distraction condition that supported the conclusions derived in the re-interpretation of distraction studies discussed above. Overall, least performance disruption occurred during ES conditions, followed by SIS, then CIS conditions. Kindergarten children's performance was not disrupted in ES conditions, but was disrupted in SIS and CIS conditions. Second-grade children's performance was not disrupted in either ES or SIS conditions, but did show decrements under CIS distraction. Fourth-grade children's performance did not exhibit disruption under any of the distraction conditions.

The results of Humphrey's (1978) study and the re-interpretation of distraction research points to a developmental progression in the ability to avoid performance disruption in the presence of particular distraction.

An important concept emerges from this argument. Rather than describe a child as distractible or not, it may be far more precise and informative to describe his/her performance in terms of "age-appropriate distractibility." That is, a preschool child who demonstrates performance disruption under SIS conditions may exhibit entirely appropriate distractibility for his/her age, and therefore should not be labeled as "distractible," a term that would falsely imply some attention disability. However, a fourth-grade child who could not avoid performance disruption with ES distraction during a sufficiently simple task demonstrates "age-inappropriate distractibility" and might well have an attention disability. Thus the use of the concept of age-appropriate distractibility allows an accurate description of a performance decrement in the presence of distraction that is independent of any diagnosis of attention disabilities.

The concept of age-appropriate distractibility would also enable an evaluation of the developmental lag often proposed as an explanation of hyperactive children's learning problems. If hyperactive children can be differentiated from normals in that they exhibit distraction effects characteristic of younger normal children, then a developmental lag in avoidance of distraction processes would be supported.

Age-appropriate distractibility is also a concept that promotes a view of attention abilities as an interaction between task characteristics and child characteristics (Krupski, in press). This view reiterates the emphasis on categorizing distractors based on the demands presented to the attender in that it stresses describing task performance in terms of attender-based standards of performance rather than in terms of performance standards for the particular experiment. That is, children may fail to perform well at the experimental task but still have performed well for their age or ability group. Often, descriptions of experimental procedures such as "below the median on task performance" are translated to child characteristics such as "the poor readers" or "those with problem solving difficulties." The confusion and mislabeling here are obvious. Concepts like age-appropriate distractibility are thus one way to avoid such semantic errors in an area prone to creating them.

Conclusions drawn from the above studies agree that what develops with age is an ability to avoid distraction that relies upon the ability to discriminate target from nontarget information within a task, and to deploy further processing capacity selectively to the target information. While there have been many investigations of children's performance of these abilities, there is as yet been little or no data available on children's awareness of the need to discriminate distractors within a task or the types of criteria children employ to define distractors or nontarget information. As mentioned earlier, successful problem solving training programs have been those that have taught specific problem solving strategies, many of which stressed target information discriminations. This suggests that a lack of awareness of differing types of information within a task and poor criteria for discriminating target information may contribute to some children's poor problem solving performance.

Task Analysis and Monitoring Processes

Task analysis involves checking for information differences within a task and an awareness of the need to be selective in deploying attention capacities among the different information sources. The monitoring of the match between task demands for selectivity and performance (e.g., avoidance of distraction) is needed to determine the effectiveness of ongoing attention direction. Both task analysis and performance evaluation are critical in determining whether a child will spontaneously discriminate among information sources and selectively direct attention capacities.

Investigations of children's abilities to perform analyses of the attention direction demands of a task, to formulate criteria for discriminating among information sources, and to evaluate their effectiveness at directing attention capacities to selected information sources have only recently appeared. Patterson and Mischel (1975) investigated avoidance of distraction in preschool children, a group often described as highly distractible. The children were told to perform a simple task in the presence of "Mr. Clown Box," a highly salient ES distractor. Time on task measures revealed significantly less distraction for children provided with specific plans for avoidance of distraction than for children merely told to resist the distraction. The results imply that preschool children do not spontaneously employ strategies to avoid distraction but can effectively use such plans when they are provided for them.

A study by Cameron (Note 3) of problem solving performance of reflective and impulsive children demonstrated that the latter group's relatively poor ability to formulate efficient strategies was coupled with a failure to regulate behavior consistently with a strategy even when one was provided. Cameron's data suggest that either an inability to self-monitor performance, an inability to employ performance feedback in the evaluation of the effectiveness of a chosen strategy, or both are problems for impulsive children.

Evidence for problems in performance monitoring in other special children comes from work with hyperactive, hypoactive, and normal children in vigilance tasks (Mack, 1975; Anderson, Note 4; Ozolin, Anderson, & Halcomb, Note 5). These authors suggest that knowledge of results affects decision criteria for vigilance performance responses such that feedback on hits increases responding while feedback on false alarms tends to slow down the rate of responding. These studies demonstrated that hyperactive children exhibited more errors when given hit feedback and fewer errors when given false alarm feedback. The studies also demonstrated that hypoactive children increased responding when given hit feedback and decreased responding when given false alarm feedback. These data suggest that both hyperactive and hypoactive children are deficient in self-monitoring of performance that is critical to the use of effective response strategies, but that they can use direct feedback on their performance to select more efficient strategies. Similar arguments are made by Brackbill (1964) and Keely and Sprague (1969), who suggest that "children need to digest 'knowledge of results'."

In summary, efficient attention direction requires several abilities. These are: (a) checking task demands for selectivity and information discrimination and determining criteria for selecting task-relevant information; (b) being selective and restricting attention capacity deployment to the relevant information sources; and (c) self-monitoring attention direction performance to determine the effectiveness of the current discrimination criteria and the need for any redirection of attention capacities. A great deal is known about children's abilities to be selective and avoid distraction, but little is known about the other necessary abilities.

Summary and Conclusions

The conceptual framework presented in this paper was designed to facilitate the investigation of attention processes in normal and distractible children. The framework is comprised of three main functions or processes of attention, namely, allocation, maintenance, and direction, and, within each function, three types of subprocesses, namely, task analysis, deployment, and monitoring. Within this framework, several critical distinctions are made between processes that have previously been treated as unitary.

Attention maintenance was distinguished from attention allocation. It was argued that attention maintenance is not a passive continuation of an initial allocation of attention to a task, but rather that it is an active sustained processing that keeps capacity deployed. Evidence that effective attention allocation does not necessarily lead to effective attention maintenance was cited in support of this distinction.

Another distinction was made between sustained processing, an aspect of attention maintenance, and avoidance of distraction, an aspect of attention direction. Implicit within this distinction is a characterization of the failure to avoid distraction as due to inappropriate criteria for discriminating relevant from distractor information. This differs from the view of distractibility found in most of the attention disability literature. There, distractibility is treated as a deficiency in sustained processing. However, this is inconsistent with existing findings, and remedial procedures based on this view have been ineffective. Evidence showing that there are children who have difficulties in sustaining attention but not in avoidance of distraction was reviewed, and it was noted that treatment programs designed to improve attention-deficient children's problem solving performance by training the ability to delay responding (to compensate for an assumed sustained processing defect) have not been successful.

An additional set of distinctions were made within the area of distraction. Classes of distraction were defined according to the difficulty of the criteria required to discriminate the distraction from the task-relevant information. External, simple internal, complex internal and temporal distractors were distinguished. The utility of this classification was demonstrated by the consistency of results revealed in an analysis of the distraction literature. This analysis led to the concept or age-appropriate distractibility, which encompasses a description of avoidance of distraction performance in terms of an interaction between task variables, such as type of distractor, and child characteristics, such as developmental level.

Reviewing the literature on children's attention within the framework presented also led to the identification of several areas where needed information is not available. In particular, little is known about children's task analysis and monitoring abilities in all areas of attention capacity deployment. These processes are not typically considered in available models of attention, but are critical in extending these models to learning and problem solving tasks. Children's abilities in appropriately altering mental effort in attention allocation was also noted as an area in need of further investigation.

While there are these gaps in information about the development of attention abilities in normal children, information about the abilities of many special populations of children described as attention deficient is even more fragmented. The literature reviewed here includes some findings about hyperactive and impulsive children, but no general analyses for any special group, or of particular processes across groups, are available. As stated in the introduction, the investigations of attention problems have generally treated attention as a unitary process, and therefore the findings have been of limited value. The investigation of component processes of attention in special children should enable the diagnosis of attention problems by functional categories, such as sustained processing or avoidance of distraction deficits, rather than the current, less analytic, diagnostic categories, such as hyperactivity and learning disability. Hopefully, this could lead to improvements in the design and evaluation of remedial programs.

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2. Hagen, J. W., & Zukier, H. Mode of inference, set and selective attention. Paper presented at SRCD, New Orleans, March 1977.

3. Cameron, R. Sources of problem solving inefficiency in relation to conceptual tempo. Paper presented at the biennial meeting of the Society for Research in Child Development, New Orleans, March 1977.

4. Anderson, R. P. The vigilance task: A computer-based technique for assessing hyperkinesis. In the symposium, "Hyperactive Children: Assessment, Treatment, and Outcome" (W. Farrar, Chair) presented at the annual meeting of the American Psychological Association, Chicago, 1975.

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Footnotes

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[1]We will only consider situations in which there is a single, clearly defined primary task. This is congruent with the situations in which children generally encounter learning and problem-solving tasks.

[2]The distraction conditions used in studies by Hagen and his associates (Hagen, 1967; Hagen & Sabo, 1967; Maccoby & Hagen, 1965; Hagen & Zukier, Note 2) do not meet this criterion. In their studies, distraction consisted of the presentation of stimuli during the intertrial interval of a central learning task and a response to those stimuli was required. While processing of such stimuli did disrupt the processing of the central task information, they are not considered distraction by our definition because a response was required (i.e., the subjects could not choose to ignore them).

Table 1

Framework of Attention Processes.

	Allocation	Maintenance	Direction
Function	control of intensity of capacity deployed	control of span of capacity deployment	control of focus of capacity deployment
Task Analysis	analysis of demands for amount of information processing and judging effort needed	analysis of demands for duration of information processing and judging sustained processing needed	analysis of demands for selectivity of information processing and judging discrimination criterion needed
Processing	mental effort	sustained processing	selectivity and avoidance of distraction
Monitoring	evaluation of match between effort expended and capacity required	evaluation of match between task progress and task goal	evaluation of match between information selection and target criteria

Table 2

Classes of Distraction

External Stimuli	Internal Stimuli: Simple	Internal Stimuli: Complex	Temporally Defined Stimuli
not part of task materials	part of task materials	part of task materials	may or may not be part of task materials
task-nontask discrimination criterion required	single discrimination criterion required (physical features)	multiple discrimination criterion required (physical features)	single or multiple discrimination criteria (temporal features)