SELECTIVE ATTENTION, NEGATIVE PRIMING, AND HYPERACTIVITY:

INVESTIGATING THE 'AD' IN ADHD

By

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ABSTRACT

Negative priming produced by hyperactive and non-hyperactive boys was measured in two experiments. The use of the negative priming paradigm allowed for the interpretation of hyperactive/non-hyperactive differences in performance within the framework of previously developed process models. Previous studies of hyperactivity have relied on measures of distractibility as an index of selective attention, and have lacked a method for exploring possible deficits in underlying attention mechanisms. Significantly reduced negative priming produced by a school-based sample of hyperactive boys as compared to age-matched non-hyperactive peers was found across spatial localization and letter identification tasks in Experiment 1. In Experiment 2, negative priming produced in a letter identification task by a clinic-based sample of boys diagnosed with Attention-deficit Hyperactivity Disorder (ADHD) was compared to that produced by non-hyperactive controls. Combined data from the letter identification tasks in Experiments 1 and 2 provided sufficient power to detect a between-group difference statistically. In an effort to account for the relatively small and variable nature of the hyperactive/non-hyperactive differences in negative priming that were found, the influence of hyperactive subgroups was examined and the theoretical interpretation of negative priming effects was reconsidered within the frameworks of three current process models. The findings of this study are particularly significant with regard to the reinforcement of inattention as a key deficit in hyperactivity.

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Because this thesis marks the end of my formal academic training, I would like to dedicate it to six educators whose impact on me as an academic and as a person has proven to be profound. I remember each of these people as if I was in their presence only yesterday, although for most of them many years have passed since I was one of their students. Nevertheless, the enduring influence of their personalities and teachings has guided me this far, and will continue to guide me for the rest of my life.

<u>Dedicated to</u>

Dorothy Spain

Arden McLaughlin

George Konrad

Darryl Chow

James Hebden

Michael Masson

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"Of all the animals, the boy is the most unmanageable."

Plato (cited in Byrne, 1988)

An eight year old boy cannot focus his attention on his work during quiet-time in his classroom. He squirms and fidgets in his seat, and seems to be distracted by every extraneous sight and sound. Within minutes, he is out of his chair and rushing around the room, visiting his friends, interfering with their work, and generally disrupting the class.

Most people would consider the pattern of behavior described above as evidence of a condition popularly known as 'hyperactivity'. If behaviors of this kind were a chronic problem for this boy, and interfered with his academic progress, it would probably be recommended to his parents that he undergo medical and psychoeducational assessments. These assessments would possibly lead to a formal diagnosis of Attention-deficit Hyperactivity Disorder (ADHD; American Psychiatric Association, 1987).

Studies indicate that approximately 10 percent of school-aged children demonstrate inattentive and overactive behaviors that are severe enough to warrant an ADHD diagnosis, with a heavily skewed ratio of males to females of up to 10 to 1 (James & Taylor, 1990; Ross & Ross, 1982; Szatmari, Offord, & Boyle, 1989b; Trites, Dugas, Lynch, & Ferguson, 1979). Compounding their hyperactivity diagnosis, the majority of ADHD children suffer from other psychiatric disturbances as well, the most frequent of which are Oppositional Defiant and Conduct disorders (approximately 50% of hyperactives: Biederman, Newcorn, & Sprich, 1991; Offord, Boyle, Fleming, Blum, & Grant, 1989; Szatmari, Boyle, & Offord, 1989; Szatmari, Offord, & Boyle, 1989b), emotional disorders (approximately 35%: Biederman et al., 1991; Offord et al., 1989; Szatmari, Offord, & Boyle, 1989b), and learning disabilities (from 10% to 90%, depending on specific diagnostic criteria: see Semrud-Clikeman, Biederman, Sprich-Buckminster, Lehman, Faraone, & Norman, 1992, for a review). The impact of ADHD spreads well beyond hyperactive children and their parents and teachers, as about half of all hyperactive children experience significant problems interacting with other children and adults, and up to 45% become involved in delinquent behaviors such as vandalism and theft sometime during their school years (Barkley, Fischer, Edelbrock, & Smallish, 1990; Brown & Borden, 1986; Campbell & Paulauskas, 1979; Milich & Laudau, 1982; Pelham & Bender, 1982; Szatmari, Offord, & Boyle, 1989a; Weiss & Hechtman, 1986). In addition to the behavioral, emotional, and social problems, almost all hyperactives fall behind their peers academically, with 35% to 60% failing at least one grade, and only 10% to 20% continuing to college or university (Barkley, Fischer, et al., 1990; Brown & Borden, 1986; Milich & Loney, 1979; Szatmari, Offord, & Boyle, 1989a; Weiss & Hechtman, 1986).

Hyperactivity has been treated with a variety of behavior modification, parent training, and medication interventions. The most effective acute treatment for hyperactivity has been stimulant medication, despite continuing concerns over its use as a chronic intervention due to a number of adverse side effects, including anxiety, emotional liability, insomnia, and appetite suppression (Barkley, 1977; Barkley, McMurray, Edelbrock, & Robbins, 1990; Schachar & Tannock, 1993). For many years it was believed that the ultimate 'cure' for ADHD was natural maturation. Unfortunately, more recent research indicates that this is true for only a minority of ADHD children, while up to 70% maintain at least some aspects of the disorder through adolescence and into their adult years (Gittelman, Mannuzza, Shenker, & Bonagura, 1985; Lambert, 1988; Lambert, Hartsough, Sassone, & Sandoval, 1987; Weiss & Hechtman, 1986).

Inattention and Hyperactivity

Patterns of inattention, overactivity, and impulsivity in children have been observed by clinicians for more than a century (Habler, 1992), but the behavioral syndrome was not labeled formally until 1957 when it became known as "Hyperkinetic Impulse Disorder" (Conners, 1990). Although a reference to *inattention* did not appear in the original diagnostic label, problems with attention have endured as a defining component of the hyperactive syndrome throughout several versions of the American Psychiatric Association's Diagnostic and Statistical Manuals (DSM-II, 1968; DSM-III, 1980; DSM-III-R, 1987; DSM-IV, 1994), and are referred to by researchers and clinicians as a central feature of childhood hyperactivity (e.g., Abikoff, Gittelman, & Klein, 1980; Atkins, Pelham, & Licht, 1985; Douglas, 1983; Douglas & Peters, 1979; Halperin, Newcorn, Sharma, Healey, Wolf, Pascualvaca, & Schwartz, 1990; Silver, 1992; Whalen, 1983). In fact, when compared to symptoms of overactivity and impulsivity, symptoms of inattention in hyperactive children are more persistent and stable over time (Hart, Lahey, Loeber, Applegate, & Frick, 1995). Furthermore, specific training in attention has been shown to improve both task performance and overall behavior in hyperactive children (Sohlberg & Mateer, 1989).

As early as the 1940's, theoreticians had equated hyperactive children's inattention and overactivity with the concept of 'distractibility', and as a remedy had suggested the removal of all potential distractors from classrooms (Strauss & Lehtinen, 1947). Although the use of extreme environmental minimization to reduce excessive activity levels was not supported by subsequent research (Cromwell & Foshee, 1960; Gardner, Cromwell, & Foshee, 1959)[1], the conceptualization of hyperactive inattention as susceptibility to distraction has remained. Excessive distractibility is

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[1]Gardner et al. (1959) actually found that activity levels increased for hyperactive subjects under a condition of zero distractors. More recently, a week-long, 24 hour-a-day, activity monitoring study confirmed that hyperactive boys are more physically active, regardless of the presence of distractors, than other boys (Porrino, Rapoport, Bahar, Sceery, Ismond, & Bunney, 1983).

assumed to occur in hyperactive children because a deficit in "selective" attention impairs their ability to focus on relevant stimuli, and thus allows irrelevant 'distractors' to interfere with cognitive processing (Ceci & Tishman, 1984; Douglas, 1988; Radosh & Gittelman, 1981; Rosenthal & Allen, 1980; Silver, 1992).

Studies of distractibility and hyperactivity typically require subjects to process a stimulus in a central task (e.g., study items for a later memory test, solve math problems, read silently, identify and respond to items with specific properties), in the presence versus absence of distracting stimuli (e.g., pictures surrounding the target stimulus, auditory noise or visual distractors in the room, irrelevant features within the target stimulus). Either poorer performance on the central task, or greater responsiveness to distractors, by hyperactive children under conditions of increased task-irrelevant stimulation has been interpreted as heightened distractibility. Using measures of distractibility of this type, some researchers have argued that hyperactive children do not selectively attend as well as control children (Sharma, Halperin, Newcorn, & Wolf, 1991), especially when the to-be-attended task is difficult (Ceci & Tishman, 1984; Radosh & Gittelman, 1981), or the to-be-ignored stimuli are very salient (Rosenthal & Allen, 1980). In their incidental learning study, Ceci and Tishman found that hyperactive children remembered more irrelevant information, and less targeted information, than normal control children. Rosenthal and Allen found that the central task performance of hyperactive children was affected to a greater degree than that of normal controls by the presence and salience of irrelevant dimensions.

In contrast, some studies have produced no evidence of diminished selective attention in hyperactive children (Aman & Turbott, 1986; Barkley & Ullman, 1975; Dykman, Ackerman, & Oglesby, 1979; Fischer, Barkley, Edelbrock, & Smallish, 1990; van der Meere & Sergeant, 1988b). Other research has indicated that although hyperactive children may be more distracted by extraneous stimuli, this distraction does not actually interfere with their cognitive processing of targeted stimuli. Bremer and Stern (1976) and Landau, Lorch, & Milich (1992) showed that hyperactive children interacted with irrelevant stimuli more than normal children. However, in both studies, central task performance of the hyperactive children was no more affected by the presence of distractors than was central task performance of control children. Bremer and Stern argued that their results highlighted an important distinction between two operational definitions of 'distractibility': as responding to task-irrelevant stimuli; and as leading to a drop in central task performance. They suggested that hyperactives are distractible in the former sense, but not in the latter.

After also finding evidence of greater attention to distractors but not poorer central task performance by hyperactives, Peters (1977) embraced Bremer and Stern's (1976) interpretation, and suggested that the distinction between definitions might explain much of the conflicting evidence in the literature on hyperactivity and distractibility. He proposed that the increased 'distractibility' of hyperactive children actually may indicate that they are better than normal children at dividing their attention between stimuli, a 'skill' that hyperactives develop in response to a need for extra sensory stimulation (Zentall, 1975). Peters suggested that seeking stimulation from task-irrelevant sources would interfere with central task performance only under certain demanding circumstances, such as in the restrictive context of the classroom. This would seem to be consistent with findings from other research studies that distractors do impair central task performance of hyperactive children when conditions are particularly arduous (Ceci & Tishman, 1984; Radosh & Gittelman, 1981; Rosenthal & Allen, 1980).

Dependent Measures of Attention

An alternative explanation for the discrepancies in the selective attention literature within hyperactivity research may be found in the choices of dependent measures and their relationships to the process of selective attention. As noted by Bremer and Stern (1976) and Peters (1977), most researchers measure distractibility as either poorer central task performance or greater distractor responsiveness under conditions of more or less accompanying irrelevant visual or auditory 'noise'. Researchers then have argued, by extension, that the degree to which hyperactives do or do not show greater distractibility than normal children is evidence of faulty or intact selective attention. A weakness of this approach is that hypothetical 'failures of selective attention' are being studied by way of the *effect* those failures would be predicted to generate: namely distractibility. Unfortunately, any 'effect' has many possible causes, and heightened distractibility in hyperactive children could be a function of a number of underlying problems other than selective attention failures per se. Hyperactives could be so physically overactive that they are not able to properly perform the central task itself, or they could be too anxious about their performance to focus their attention, or they might lack the motivation necessary to try to attend, particularly in demanding tasks. These and other alternative explanations of hyperactive children's relatively poor performance under conditions of increased distraction must be excluded before such results can be accepted as evidence of a true selective attention deficit.

Problems with measures of attention processes in hyperactivity research are not limited to studies of selective attention. Evidence that is purported to show that hyperactive children have poor "sustained" attention often has left the precise role of the attention component open to question (e.g., Aman & Turbott, 1986; Dykman, et al., 1979). Similarly, studies that have failed to find hyperactivity-related deficits in sustained attention have relied on assessments of declines over time on task in simple measures of performance such as response time and errors (Schachar, Logan, Wachsmuth, & Chajczyk, 1988; van der Meere, Wekking, & Sergeant, 1991). Attempts to use other, more sophisticated tests of sustained attention have not resolved the issue (Seidel & Joschko, 1990, van der Meere & Sergeant, 1988a), and reviewers of research involving the popular Continuous Performance Task have concluded that there is no evidence of a specific sustained attention deficit in hyperactives (Corkum & Siegel, 1993, 1995; Koelega, 1995). As with research on selective attention, the equivocal nature of the literature may reflect the fact that dependent measures typically represent the hypothesized 'effect' of sustained attention failures. Examinations of sustained attention and hyperactivity have relied on measures of children's ability to maintain overall task performance over time. As an alternative approach, Swanson (1983) has argued that evidence in support of a true deficit in sustained attention should be limited to situations in which an attention *process* or *mechanism* can be shown to decrease in the efficiency of its functioning as time on task increases.

Basic Mechanisms of Selective Attention

Consistent with Swanson's (1983) recommendation for the area of sustained attention research, a preferred approach to uncovering impairments in selective attention would be to assess the functioning of basic mechanisms that are hypothesized to underlie the selective attention process. By working forward to the selective attention process from its underlying mechanisms a more precise understanding of the nature of any deficits may be gained, and the confounding explanations that result from working backward from effects of failed attention may be avoided. The focus of the present research approach is on the *cause* of selective attention failures, rather than on the *effects* those failures generate.

To study mechanisms purported to underlie cognitive processes such as selective attention, experimental tasks that allow testing of process models are required. One such task that has proved to be very useful in attention research over the past two decades measures a phenomenon known as Negative Priming. The critical experimental manipulation in studies of negative priming, called an "ignored repetition" trial by Tipper (1985), involves the presentation of sequential pairs of stimulus displays in which the target in the second display was a distractor in the first display. The negative priming effect is defined as slowed response times, or greater likelihood of errors, in this ignored repetition condition than in a control condition in which there is no relation between items in consecutive displays (Dalrymple-Alford & Budayr, 1966; Keele & Neill, 1978; Lowe 1979, 1985; Neill, 1977; Neill & Westberry, 1987; Tipper, 1985; Tipper & Cranston, 1985). Negative priming has been demonstrated in normal adults using a variety of stimuli, including letters (Allport, Tipper, & Chmiel, 1985; Neill, Lissner, & Beck, 1990; Neill & Valdes, 1992; Tipper & Cranston, 1985; Tipper, Weaver, & Houghton, 1994), words (Milliken & Joordens, 1996; Yee; 1991), pictures (Allport et al., 1985; Tipper, 1985), and spatial locations (Shapiro & Loughlin, 1993; Tipper & McLaren, 1990; Tipper et al., 1994; Tipper, Weaver, Kirkpatrick, & Lewis, 1991).

A widely adapted process model of the ignored repetition effect is rooted in early theorizing by Neill and his colleagues (Neill, 1977; Neill & Westberry, 1987) and by Tipper and his colleagues (Tipper, 1985; Tipper, MacQueen, & Brehaut, 1988). Both Neill and Tipper argued that the act of selective attention requires the cognitive isolation of a targeted stimulus from a background of potentially distracting irrelevant stimuli, and that this process occurs by way of two concurrently operating basic mechanisms; excitation of representations of to-be-attended stimuli, and inhibition of representations of to-be-ignored stimuli. According to their model, the process of selective attention begins with the processing and identification of all components of a task-relevant stimulus display, regardless of the components' potential roles as targets or distractors. Following this initial processing, mental representations relating to target stimuli continue to receive excitatory processing, while mental representations associated with irrelevant stimuli are actively inhibited. Failures to cognitively inhibit irrelevant stimuli would lead to impaired selective attention because of the increased difficulty in separating targets from the background noise.

Much of the evidence supporting the existence of an inhibition mechanism has come from Negative Priming studies. If mental representations associated with distractors are inhibited to efficiently focus attention on targets in the stimulus display, then subsequent cognitive processing of those distractors as targets should be impaired, resulting in the slower and less accurate responses that typically comprise the ignored repetition effect.

Negative Priming and Special Populations

In addition to research with normal young adults, the ignored repetition effect has proven to be a useful measure in studies directed at clinical and aged populations. In a series of studies, Beech and his colleagues found that schizotypal personality traits in normal adults were inversely related to the magnitude of ignored repetition effects, suggesting that disorders such as schizophrenia may be related to deficits in cognitive inhibition (Beech, Baylis, Smithson, & Claridge, 1989; Beech & Claridge, 1987; Beech, McManus, Baylis, Tipper, & Agar, 1991; Claridge, Clark, & Beech, 1992). Negative priming studies contrasting diagnosed schizophrenic patients with control subjects also have produced evidence suggesting that schizophrenics may suffer from an inability to inhibit irrelevant extraneous information (Beech, Powell, McWilliam, & Claridge, 1989; Park, Puschel, Hauser, & Hell, 1995).

In other research with psychiatric patients, Enright and Beech (1990, 1993) found that people with obsessive-compulsive disorder also did not produce negative priming effects. Fox (1994a) observed that ignored repetition effects were produced by low trait-anxious subjects, but not by their high trait-anxious counterparts. In research with cognitively challenged subjects, one study showed that learning disabled children produced ignored repetition effects that were significantly smaller than those produced by age-matched normal controls (Tannock & Marriott, 1992). Similar findings have been reported in studies of mentally retarded subjects (Cha & Merrill, 1994) and closed-head-injury patients (Vakil, Weisz, Jedwab, Groswasser, & Aberbuch, 1995).

Results from several negative priming studies with aged subjects have been interpreted as indicating that the elderly do not inhibit distractors as well as, or in the same manner as, younger adults (Hasher, Stoltzfus, Zacks, & Rypma, 1991; Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994; McDowd & Oseas-Kreger, 1991; Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993; Tipper, 1991). These results have led some researchers to suggest that distractor inhibition in the aged is not as well organized and goal-oriented as it is in younger adults (Kwong See, 1994; McDowd & Filion, 1995; but see Sullivan & Faust, 1993).

Negative Priming and Hyperactivity

Impulsive behaviors such as not waiting for one's turn, shouting out comments and questions, and acting before thinking are common features of hyperactivity. Recent research has linked impulsivity to reduced negative priming. In a study of teacher-identified impulsivity, Visser, Das-Smaal, and Kwakman (1996) found that high impulsive children produced significantly less negative priming than low impulsive children. The authors interpreted their findings as support for the notion that impulsivity is a result of deficient inhibition.

Of greatest relevance to the present study, negative priming tasks also have been used in research with hyperactive children. McLaren (1989) measured the ignored repetition effects produced by hyperactive and control children in two separate tasks, using pictures and STROOP color-words as stimuli (Stroop, 1935). In both tasks, she found that hyperactive children did not produce statistically significant ignored repetition effects. With the STROOP stimuli, neither of two subgroups of hyperactives (with and without comorbid oppositional disorder) generated significant ignored repetition effects. With pictures as stimuli, only one of the hyperactive subgroups produced a significant effect. The normal control children produced significant ignored repetition effects with both types of stimuli. Unfortunately, McLaren's results were somewhat inconclusive as analyses directly comparing the hyperactive and control groups' ignored repetition effects failed to reveal statistically significant differences, possibly due to the small numbers of subjects in each group (12 in each hyperactive group and 14 control subjects).

Normal Development of Distractor Inhibition

There is a considerable literature within child development research indicating that younger children do not selectively attend to stimuli as well as older children (for reviews, see Hagen & Hale, 1973; Lane & Pearson, 1982; Pick, Frankel, & Hess, 1975). Across a series of studies, Enns and his colleagues (Enns & Akhtar, 1989; Enns & Cameron, 1987; Enns & Girgus, 1985) have demonstrated that young children are less able to focus their attention on relevant stimuli than older children and adults. Their results are consistent with other research showing a developmental decrease in interference caused by irrelevant stimuli (Boucugnani and Jones, 1989; Doyle, 1973; Well, Lorch, and Anderson, 1980).

As with hyperactive children, one weakness in the selective attention process in young normal children could be poor inhibition of irrelevant stimuli. Tipper, Bourque, Anderson, and Brehaut (1989) investigated this possibility by having young children perform negative priming tasks. They found that their seven year-old subjects did not produce significant ignored repetition effects in tasks using two different types of stimuli. McLaren (1989) also found evidence that, among normal children, only those younger than 8 years old failed to produce significant ignored repetition effects in a negative priming task using pictures as stimuli.

In the experiments conducted by both Tipper et al. (1989) and McLaren (1989), children were required to respond to target stimuli by identifying them (i.e., "name" the color or picture). An alternative method for carrying out a negative priming task is to have subjects indicate the location of a target in space (i.e., the location of the target in a display on a computer monitor), rather than the identity of the target (e.g., Shapiro & Loughlin, 1993; Tipper & McLaren, 1990; Tipper et al., 1994; Tipper, Weaver, Kirkpatrick, & Lewis, 1991). Tipper and McLaren (1990) argued that selective attention to, and hence inhibition of, locations in physical space should develop earlier than selective attention to object identities because children must develop the ability to move through and manipulate their physical environments long before they begin to overtly identify and categorize objects according to linguistically idiosyncratic labels. To test this hypothesis, they had children as young as five years old indicate the positions of targets appearing in different spatial locations on a computer screen while ignoring distractors that appeared in other positions. Employing this type of negative priming paradigm, Tipper and McLaren found that children as young as five years old produced ignored repetition effects equivalent to those generated by young adults.

Evidence supporting the notion that cognitive immaturity is associated with reduced negative priming in 'target identification' tasks, but not in spatial location tasks, also has been found in a pair of studies with mentally retarded young adults (Cha & Merrill, 1994; Merrill, Cha, & Moore, 1994). Using a letter-based identification task, Cha & Merrill found that their mentally retarded subjects failed to produce a negative priming effect. In contrast, when a spatial location negative priming task was employed no difference was seen between the ignored repetition effects produced by mentally retarded and control subjects.

Hyperactivity and Developmental Delay

Evoked Potentials and Frontal Lobe Tasks. Partially because their behavior has the uncontrolled, 'immature' nature of very young children, hyperactives have been suspected to suffer from some form of cognitive maturational lag (Kinsbourne, 1973). Several studies have attempted to investigate this possibility by examining hyperactive and control children across several age groups. Results have been mixed from studies measuring evoked brain potentials, with some researchers arguing in favor of a developmental delay in hyperactives (Buchsbaum & Wender, 1973; Rapoport & Ferguson, 1981) and others suggesting that there are developmental inconsistencies between normal and hyperactive children, but no evidence of a simple delay in maturation (Callaway, Halliday, & Naylor, 1983; Satterfield & Braley, 1977).

More recently, it has been shown in several studies that hyperactive subjects perform poorly on tasks used typically with frontal lobe injured patients (Barkley, Grodzinsky, & DuPaul, 1992; Gorenstein, Mammato, & Sandy, 1989; Ross, Hommer, Breiger, Varley, & Radant, 1994). Studies that have directly compared the development of hyperactive and normal children using frontal lobe tasks have produced results that are consistent with the maturational lag hypothesis, placing the hyperactive children's development two to four years behind, but along the same course as, that of their normal peers (Boucugnani & Jones, 1989; Chelune, Ferguson, Koon, & Dickey, 1986; Shue & Douglas, 1992).

Selective Attention Tasks. Parallels between hyperactive and young normal children's selective attention also have been demonstrated. When subjects were required to shadow one of two messages in a dichotic listening paradigm, Peters (1977) found that hyperactive children allowed a higher rate of intrusions from the unattended message than did normal control children. Doyle (1973) found evidence of the same susceptibility to intrusions from the distracting message with younger compared to older normal children in her dichotic listening study. Other similarities between hyperactives and young normals have been noted in selective listening studies by Prior, Sanson, Freethy, and Geffen (1985; cf. Sexton & Geffen, 1979), and Pearson and Lane (1990).

In contrast, results from attention studies using visual stimuli generally have not confirmed the auditory research findings. Pearson and Lane (1990) reported results from visual attention studies that were not consistent with a developmental delay interpretation of hyperactive inattention. Similarly, Peters (1977) did not find a hyperactive/control parallel to Hagen's (1967) normal development findings using a visual incidental learning paradigm. In her study with hyperactive and normal children, McLaren (1989) reported results from a number of dependent measures that were both consistent and inconsistent with the maturational lag hypothesis, although McLaren did find some evidence of a parallel between the ignored repetition effects produced by her hyperactive and by her youngest normal children.

Summary

A significant number of school aged children, chiefly boys, are diagnosed with hyperactivity, a disorder characterized by inattention and overactivity that is frequently associated with academic and social failures as well as other serious psychiatric conditions. Although the fact that hyperactive children have profound attention problems is generally accepted by clinicians and lay-people, the evidence from research studies is at best equivocal with regard to the existence, extent, and nature of any attention-deficit that may be manifested.

Most of the research that has been conducted has arisen from the concept of distractibility and its assumed relationship to faulty selective attention processing. Some of these studies have shown that hyperactive children are poorer selective attenders than their normal peers, particularly when tasks are demanding (Ceci & Tishman, 1984; Radosh & Gittelman, 1981; Rosenthal & Allen, 1980). Other studies have failed to find any indication that hyperactive children have impaired selective attention (Aman & Turbott, 1986; Fischer et al., 1990; van der Meere & Sergeant, 1988b), or have found hyperactives to be more 'distractible', but not less 'attentive' (Bremer & Stern, 1976; Landau et al., 1992; Peters, 1977).

A potential problem with most studies on selective attention and hyperactivity has been a reliance by researchers on the assumption that measures of distractibility are reliable and valid representations of the underlying selective attention process. As an alternative approach, it has been suggested that researchers who are investigating attention and hyperactivity should examine the *basic mechanisms* that are hypothesized to underlie attention, rather than the 'effects' that result from attention failures (Swanson, 1983). One such hypothesized mechanism of selective attention is inhibition of potential distractors (Neill & Westberry, 1987; Tipper, 1985). Distractor inhibition has been operationally defined within the negative priming paradigm as a key component of the ignored repetition effect: responses to stimuli are impaired immediately after those same stimuli have served as distractors in a previous display. This paradigm has been used successfully to discriminate between young adult subjects and both children and the aged, and between normal subjects and a number of clinically defined special populations.

One study that has used negative priming tasks to compare normal and hyperactive children has produced encouraging preliminary findings (McLaren, 1989). In separate tasks, normal control children produced significant ignored repetition effects while hyperactive children did not.

It has been suggested that hyperactive children are developmentally delayed, and therefore that their ability to attend is like that of younger normal children. While some support has been found for this hypothesis, particularly with regard to auditory selective attention, the results from studies of visual selective attention are weak. However, there is some evidence of similarities between ignored repetition effects produced by hyperactive and young normal children (McLaren, 1989).

Objectives of Present Research

The purpose of the present research was to investigate further the possibility that negative priming is sensitive to the differences in selective attention that exist between hyperactive and non-hyperactive children. By examining differences between hyperactive boys and their non-hyperactive peers in a task for which precise process models can be formulated and tested, a clearer understanding of the degree and nature of hyperactive children's attention deficits may be gained. In the two experiments reported, samples of hyperactive children were identified in general public and clinical settings, and by questionnaire and interview methods, in an effort to evaluate the reliability and scope of any hyperactive/control differences. Furthermore, the developmental lag hypothesis was assessed by comparing the pattern of ignored repetition effects shown by hyperactive children across two negative priming tasks, and the patterns produced by different age groups of non-hyperactive children.

In the first experiment, a large sample of elementary school boys generated ignored repetition effects in two negative priming tasks, as well as completing a search task that required finding a cartoon character in pictures filled with distractors. The parents and teachers of the boys filled out separate standardized questionnaires regarding hyperactive symptomatology, the results of which were used to identify groups of hyperactive and non-hyperactive boys. The group of non-hyperactive boys was divided into age-defined subgroups for the purpose of developmental analyses, and groups of hyperactive and non-hyperactive children were created by individually matching subjects on age and other key variables.

Although McLaren (1989) found evidence that hyperactive children failed to produce ignored repetition effects in some negative priming tasks, she did not uncover significant differences when the ignored repetition effects produced by her hyperactive and non-hyperactive subjects were directly compared. Experiment 1 was an attempt to extend the suggestive findings from McLaren's study, by demonstrating significant between-group differences in the ignored repetition effects produced by hyperactive versus age-matched non-hyperactive children. A result of this type could be interpreted to indicate that hyperactive children have difficulty suppressing their attention to distracting information, and thus have trouble focusing their attention on targeted stimuli.

Experiment 2 involved children who were assessed for hyperactivity in a hospital psychiatric clinic in an effort to gather a more severely attention disordered group of subjects. ADHD diagnoses were assigned based on thorough interviews with parents and teachers. Children performed a negative priming task very similar to one of the tasks used in Experiment 1, and hyperactive/control comparisons of ignored repetition effects were made in an effort to further investigate the relationship between hyperactivity and negative priming.

By examining a hypothesized selective attention mechanism, using a paradigm that has proven to be a successful research tool with a variety of populations, and doing so in children with differing degrees of hyperactivity, the present research project was designed to bring needed new evidence to the investigation of the attention deficit component of the hyperactive syndrome.

Experiment 1

Two different experimental tasks were employed in Experiment 1. One task was modeled after that used by Tipper and McLaren (McLaren, 1989, Tipper & McLaren, 1990, Tipper, Weaver, Kirkpatrick, & Lewis, 1991) and required subjects to respond to the spatial location of a target character shown on a computer screen. The other task was modeled after one used previously by Neill and his colleagues (Neill et al., 1990; Neill & Valdes, 1992) and required subjects to decide whether two letters within a five-letter string had the same or different identities (i.e., were the same letter). Normal subjects have been shown to produce significant ignored repetition effects in both of these tasks.

In addition to these two tasks, a more conventional measure of the effect of impaired selective attention was used in Experiment 1. Subjects were asked to search for either of two specific, colorfully dressed human characters in pictures filled with cartoon-like drawings of people. The searches were particularly difficult because of the density of non-target characters, many of whom were dressed in clothes similar to those of the targets (Duncan & Humphreys, 1989). Numerous comical scenes within each picture, and the random addition of articles similar to those articles associated with the targets, created further distraction.

Two previous studies indicated that hyperactive children might have considerable difficulty with the cartoon search task in Experiment 1. In a study with mentally challenged teenagers, Melnyk and Das (1992) showed that subjects categorized as 'low-attention' were slower to search through a set of simple pictures than those categorized as 'high-attention'. Aman and Turbott (1986) had subjects search for squares among other geometric figures surrounded by cartoon drawings and found that hyperactive children made significantly more errors than control subjects. It was predicted that if the hyperactive children in Experiment 1 of the present study suffered from impaired selective attention, they would be slower than their non-hyperactive peers at finding the target characters in the cartoon pictures.

An additional aim in Experiment 1 was to examine the possibility that the pattern of ignored repetition effects produced by hyperactive children resembles that of young non-hyperactive children. Previous research has indicated that, unlike older children and adults, young normal children do not produce significant negative priming effects in tasks that require responses based on stimulus identities (McLaren, 1989; Tipper et al., 1989). In contrast, no evidence of age-related differences in ignored repetition effects has been documented in tasks requiring a response to the spatial location of a stimulus (Tipper & McLaren, 1990). By testing subjects on both spatial localization and letter identification tasks, differences in the development of the putative inhibitory processing of spatial location and letter identity could be assessed directly. Investigation of the hypothesis that selective attention of hyperactive children is similar to that of young normal children required the combination of two key findings. First, the young non-hyperactive boys would have to produce smaller ignored repetition effects than the older non-hyperactive boys in the letter identity task, but not in the spatial location task. Second, a similar pattern of abnormally small ignored repetition effects in the letter identity task, but not in the spatial location task, would have to be found with hyperactive boys as compared to age-matched non-hyperactive controls. The co-occurrence of these two separate developmentally and clinically-based results would be consistent with a view of hyperactive inattention as a problem of maturational lag.

Method

Subjects

Forms granting permission to participate in the research study were sent to the parents of 442 boys, aged 7 years 0 months to 10 years 11 months, from six elementary schools in Hamilton and Dundas, Ontario. Of those forms, 313 were returned, with parents of 248 children agreeing to have their sons take part. Parents of thirteen of these children subsequently withdrew their consent before the experimental sessions began,[2] and two other boys did not complete any part of their scheduled sessions.[3] In addition to the consent of their parents, assent was gained from all children themselves.

Of the 233 boys for whom there were completed hyperactivity questionnaires from parents and teachers, and who completed at least part of the experimental session, 31 were excluded from any analyses: 12 because they were taking the stimulant medication methylphenidate at the time of the study and 19 because they demonstrated serious reading problems on the WRAT-R Reading subtest (see *Reading Assessment* below). Based on the results from the hyperactivity questionnaires completed by the parents and teachers, 37 of the 202 remaining children were categorised as hyperactive, 144 as non-hyperactive, and 21 as borderline (see *Hyperactivity Assessment* below).

To provide a contrast adult group for the developmental analyses, 18 males who were enrolled in introductory psychology at McMaster University in Hamilton, Ontario performed the experiment in exchange for partial course credit.

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[2]Parents of six boys did not return the hyperactivity questionnaire that was sent home to them, despite repeated requests. Seven other children were withdrawn immediately after their parents received the hyperactivity questionnaire.
[3]One boy had a severe visual impairment that rendered the experimental session impossible to carry out and one other boy became unavailable because of other commitments.

Hyperactivity Assessment

Behavior descriptions were gained via Conners Parent and Teacher Rating Scales (Conners, 1969, 1970). These questionnaires have been recommended for, and widely used as a method of, grouping subjects in hyperactivity research (Edelbrock & Rancurello, 1985; Silver, 1992). Subgroups of children were constructed in the present study using Hyperactivity Index T-scores (age-standardised scores with a mean of 50 and a standard deviation of 10) generated in both the parent and teacher questionnaires. If a boy's parents or teacher produced a Hyperactivity Index T-score at or above the 95th percentile (at or above +1.6 standard deviations from the mean), that boy was placed in the hyperactive group. If both T-scores placed a child below the 87th percentile (at or below +1.1 standard deviations from the mean), that boy was classified as non-hyperactive. Children who failed to meet the hyperactivity criteria at home or school, and who had one or both T-scores fall between the 87th and 95th percentiles, were categorised as borderline and were not included in the analyses. No one except the experimenter was aware of the group membership of any boy.

Reading Assessment

Numerous studies have shown that hyperactive children are worse at reading than their non-hyperactive peers (e.g., Barkley et al., 1992; Boudreault, Thivierge, Cote, Boutin, Julien, & Bergeron, 1988; Carter, Krener, Chaderjian, Northcutt, & Wolfe, 1995). In a study that controlled for factors such as age and comorbid hyperactivity, Tannock and Marriott (1992) reported evidence that learning disabled children (most of whom were reading disabled) produced reduced ignored repetition effects in a letter identity negative priming task. To ensure that the present study would provide a strong test of the hypothesis that hyperactivity per se is associated with reduced negative priming, reading disabled subjects were excluded. Accordingly, the word recognition ability of each child in the present study was assessed using the Reading subtest of the WRAT-R (Jastak & Wilkinson, 1984). Boys who scored greater than 1.5 standard deviations below age-based norms were considered to have a serious reading disability and were excluded from any data analyses.

Letter Identity Negative Priming Task

Materials. The critical stimuli were 16 uppercase consonants: B, C, F, G, H, J, K, L, M, N, Q, R, T, W, X, and Z. The video screen image of each letter was 4mm wide and 6 mm high. The stimuli were presented as a row of five letters side-by-side, with the first, third, and fifth letters being identical to each other, and different from the second and fourth letters. The second and fourth letters were identified by small horizontal lines placed beneath them. When viewed from a distance of 1 meter, each letter subtended 0.23 by 0.34 degrees of visual angle, the space between adjacent letters was 0.06 degrees, and the edge-to-edge width of a five letter group was 1.39 degrees, equal to the approximate size of the foveal floor (area of maximum visual acuity) on the human retina (Duke-Elder & Wybar, 1961).

Design. Subjects were given a response box with a left button labelled "S" and a right button labelled "D". They were instructed to press the "SAME" ("S") button if the two underlined letters were the same as each other, and to press the "DIFFERENT" ("D") button if those two letters were different.

On every trial subjects saw and responded to two letter strings in sequence (the prime and probe). On ignored repetition trials, the distractor letter in the prime became one or both of the target letters in the probe, while the prime targets and probe distractors were unrelated (see Figure 1). Each ignored repetition trial was paired with a matched control trial that had the same probe letter string, but differed in that there was no overlap between the particular letters in the prime

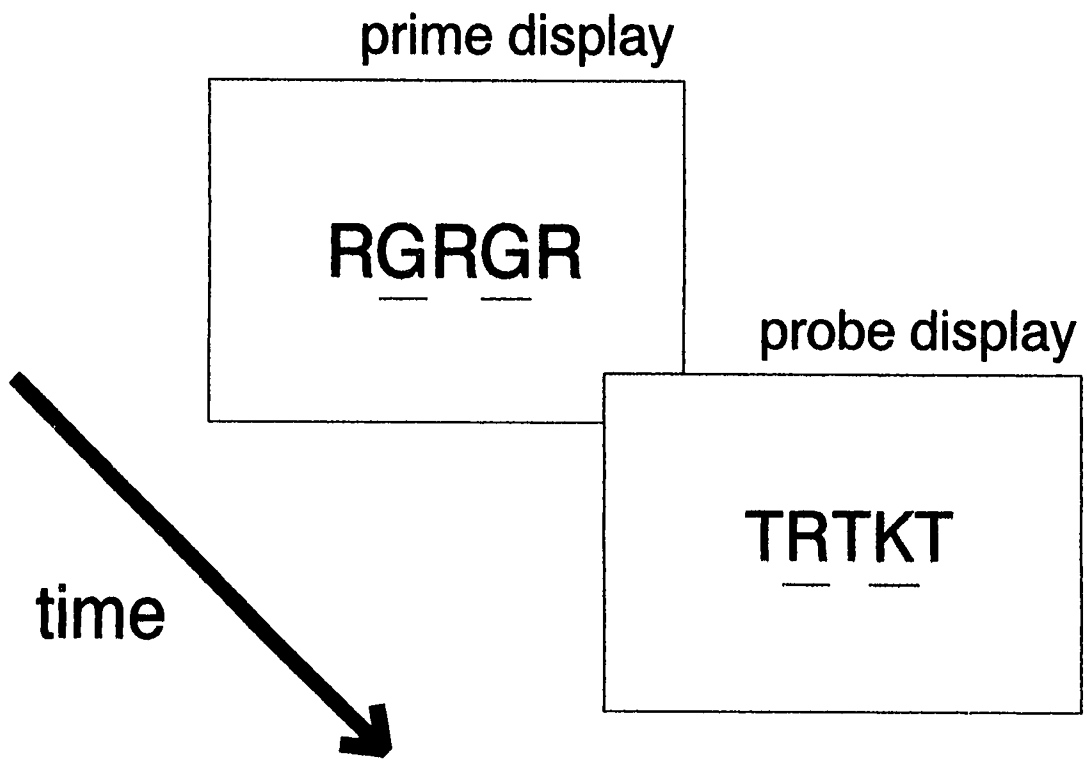

Figure 1. Example of an ignored repetition trial in the letter identity negative priming task in Experiment 1 (not drawn to scale).

and probe. The ignored repetition and control trials also were matched regarding the combination of correct responses ("S-S", "S-D", "D-S", "D-D") to the prime and probe displays.

The task began with a practice block of 12 ignored repetition and 12 matched control trials. The remaining trials were organised into two blocks of 20 ignored repetition trials along with their matched control trials. The trials in each block were randomly ordered under the constraints that consecutive trials not contain any of the same letters, and that at least two trials occurred between presentations of a given probe letter string. Although the same ordering of trial types was used for all subjects, the specific letters presented on given trials were varied between subjects in a Latin Square design. A check of the ordering of trials revealed that ignored repetition trials occurred immediately after other ignored repetition trials on 19 of their 40 presentations.

Spatial Location Negative Priming Task

Design and materials. Each stimulus display contained a "0", the target, and a "+", the to-be-ignored item. The stimuli were presented in two of four locations on a computer screen that were identified by small horizontal lines, in a wide U-shaped configuration. Subjects had a response box with four buttons shaped in an analogous configuration to the positions indicated on the monitor, and they were told to press the button that matched the location of the "0".

Trials consisted of prime/probe display pairs. All possible combinations of prime/probe target/distractor locations were used, with the exception of a distractor occupying the same location in both displays on the same trial. In an ignored repetition trial, the probe target appeared in the same location as the prime distractor (see Figure 2). In the matched control trial, an identical probe display was preceded by a prime display in which the target and distractor occupied the two locations **not** filled in the probe. To avoid predictability of probe target location, one quarter of

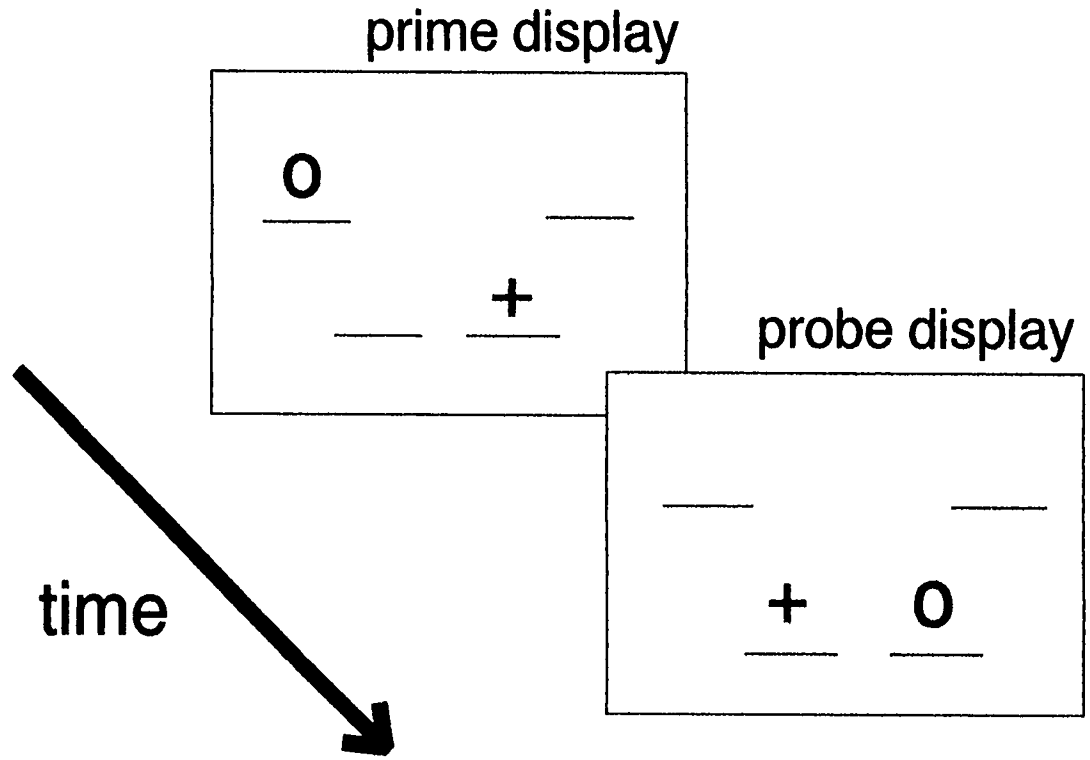

Figure 2. Example of an ignored repetition trial in the spatial location negative priming task in Experiment 1 (not drawn to scale).

the trials had prime and probe targets in the same location. These trials and their matched control trials will not be considered further.

The organization of the trials was very similar to that in the letter identity task. A block of 24 practice trials was followed by two blocks of 48 trials, each containing 12 ignored repetition trials and their 12 matched controls. Trials were randomly ordered under the constraints that prime displays not be identical to the preceding trial's probe display, and that at least one trial separated matched ignored repetition/control trial pairs. All subjects saw the same ordering of trials.

Calculation of Ignored Repetition Effects

Calculation of ignored repetition effects was identical for the two computer tasks. All trials in which there was an error in responding to the prime **and/or** probe displays were excluded from the response time data. Because every ignored repetition trial had its own control, calculations of response time effects were carried out on a trial by trial basis by subtracting the probe response time for a given ignored repetition trial from the probe response time for its paired control trial.

All trials in which there was an error in the response to the prime display were excluded from the error rate data. Effects on error rates were calculated by subtracting the percentage of probe errors on ignored repetition trials from the percentage on their matched control trials.

Computer Task Procedures

The negative priming tasks were carried out using an Apple IIe computer interfaced with a Mountain Clock to provide millisecond timing. Stimuli were displayed in 40 column format on a green monochrome video screen under normal florescent room lighting. Subjects were seated at a table approximately 1 m away from the display screen and with the response box in front of them. Every trial began with the word "READY" in the middle of the video screen. The experimenter pressed a key on the computer's keyboard to start the trial and the READY signal was immediately replaced by a line of five asterisks in the letter identity task, and by the location markers in the spatial location task. These orienting displays were replaced 500 ms later by the prime displays, which remained on the screen until the subject's response. Following a 500 ms interval (blank screen in the letter identity task, location markers in the spatial location task), the probe display was presented. The subject's button press cleared the screen, and correct response latencies were presented in the upper left corner of the screen. After a 2000 ms delay the screen cleared and the READY signal reappeared.

If a subject was pressing a response button at the programmed onset time for a display, the computer beeped, did not present the display, and the experimenter issued a warning. If a response button was being pressed at the onset of a prime display then the trial was repeated. If a response button was being pressed at the onset of a probe display then that trial was discarded and the experiment proceeded to the next trial.

The instructions for the computer tasks, including examples of trials, were presented on the computer screen. The instructions were read by the experimenter for the children, and adult subjects were asked to read the instructions to themselves. The final comment made to the subjects by the experimenter before the start of the tasks emphasised that responses should be made quickly, but accuracy was of primary importance.

At the end of the practice trials, subjects were told that the computer now would promote them through military ranks as they accumulated correct responses. Promotions were given after 19 correct responses (20 for adult subjects) and were presented below the response times. Each task required 15-20 minutes to complete.

Cartoon Picture Search

Subjects were instructed that they would be shown a series of six cartoon pictures filled with characters and objects, and that their task was to find either of two specific characters. Search times were measured using a stopwatch, with a maximum time of three minutes per picture. Subjects who could not find one of the target characters in a given picture within the allotted time were given a score of 180 seconds. As a warm-up for each subject, the easiest picture based on pre-testing was presented first, and those search times were excluded from the analyses. The remaining five pictures were shown in the same order to all subjects.

Session Format

The format of each session consisted of a computer task, the WRAT-R reading test, the second computer task, and the cartoon picture search. At the beginning of each session, suitable visual acuity of each subject was confirmed using a standard eye chart. Order of the computer tasks was counterbalanced across age groups, as was time of day for the sessions. Children were scheduled in sessions so that each hyperactive boy performed the identical tasks, in the same order, at the same time of day as an age-matched non-hyperactive control child from the same school.

Results

Statistical Methods

In a large number of studies, it has been shown that healthy, young, normal adult subjects produce larger ignored repetition effects than do a wide variety of special populations of subjects. These studies have found abnormally small ignored repetition effects to be associated with schizophrenic and anxious adults, with learning disabled children, with mentally retarded subjects, and with very young and very old normal subjects (Beech & Claridge, 1987; Beech et al., 1991; Cha & Merrill, 1994; Claridge et al., 1992; Fox, 1994a; Hasher et al., 1991; Kane et al., 1994; McDowd & Oseas-Kreger, 1991; Stoltzfus et al., 1993; Tannock & Marriott, 1992; Tipper, 1991; Tipper et al., 1989). In addition, McLaren (1989) found that hyperactive children produced non-significant ignored repetition effects in the only previous study to examine the relationship between hyperactivity and negative priming. Taken together, the consistent findings of smaller negative priming effects with special populations of subjects, including hyperactive children, suggest that the appropriate hypothesis to test in the present study for hyperactive/control group comparisons of ignored repetition effects is one-tailed. To remain consistent with the analyses of the ignored repetition effects, and given several previous findings of greater distractibility in hyperactive than in non-hyperactive children (Bremer & Stern, 1976; Ceci & Tishman, 1984; Landau et al., 1992; Radosh & Gittelman, 1981; Rosenthal & Allen, 1980; Sharma et al., 1991), one-tailed tests of statistical significance were applied in the present study for hyperactive/non-hyperactive comparisons of cartoon search times as well. All other comparisons used two-tailed tests, unless otherwise indicated. Analyses of variance (ANOVAs) were followed by Newman-Keuls post hoc tests when appropriate. All critical α levels were set at $p < .05$.

Because the hyperactive and control subjects were individually matched on age, time-of-day, and task order variables, paired sample t-tests were used for all hyperactive/non-hyperactive contrasts.

Developmental Analyses

The 144 non-hyperactive children were rank ordered from youngest to oldest and then divided into 4 quartiles with 36 boys in each for the purpose of the developmental analyses. Mean ages (years:months) for each subgroup were 7:9, 8:10, 9:8 and 10:6 from youngest to oldest quartile. As an assessment of baseline levels of responding, response times and error percentages from the prime and probe control trials for both tasks were compared across the four age quartiles of children, and then the baseline responding of each age quartile was compared to that of the university undergraduates. The hypothesis that negative priming emerges at different ages in different tasks was evaluated by comparing ignored repetition effects for the two tasks across all age groups. Finally, effects of distractors for different ages were assessed by comparing the means of the median cartoon task search times for the five groups.

Control trials. Means of median response times and mean error percentages from the prime and probe control trials in the spatial location and letter identity tasks are shown in Table 1a. As an assessment of changes in response patterns with age, One-way ANOVAs and accompanying analyses for possible linear and quadratic polynomial components were carried out on the data from the four age quartiles of children. The results of the analyses are presented in Table 1b and as can be seen, the omnibus F values from all of the response time analyses were significant. In contrast, none of the error percentage ANOVAs yielded significant omnibus F values. The analyses of polynomial components revealed significant linear terms for each of the response time analyses, suggesting a relatively regular decrease across age groups in speed of response. Neither of the polynomial components in the error percentage analyses of the spatial location task were significant, but the analyses of the error percentages in the letter identity task revealed significant linear terms, indicating that error percentages increased from the youngest to oldest children.

Results of comparing baseline response levels of each group of children against those of the adult subjects using Dunnett's test (Kirk, 1968) are shown in Table 1a. Consistent with the linear decrease in response times across the age groups of children, the adults were faster to respond than the oldest children. However, unlike the older children, the adults did not respond

Table 1a

Mean (Standard Deviation) Response Times and Error Percentages to Negative Priming Task Control Trial Displays for Adults and Age-defined Subgroups of Non-hyperactive Children in Experiment 1.

		Age-defined Subgroup of Non-hyperactive Children				
		1st Quartile	2nd Quartile	3rd Quartile	4th Quartile	Adults
Spatial Location Task						
Primes	RT[a]	800* (191)	775* (204)	600* (112)	568* (117)	391 (57)
	EP[b]	1.56 (2.14)	2.61* (3.09)	2.14 (2.56)	2.20 (2.39)	0.46 (0.89)
Probes	RT	773* (186)	721* (159)	578* (97)	547* (115)	372 (50)
	EP	1.89 (2.33)	2.16 (2.37)	2.67* (2.69)	2.40* (3.45)	0.47 (1.15)
Letter Identity Task						
Primes	RT	1778* (454)	1595* (446)	1209* (281)	1109* (209)	708 (96)
	EP	1.41 (2.04)	2.32 (2.87)	3.13 (3.29)	3.27 (4.18)	1.53 (1.74)
Probes	RT	1515* (396)	1350* (399)	1053* (231)	935* (139)	628 (104)
	EP	3.09 (2.67)	3.59 (3.30)	3.60 (3.26)	4.95* (4.44)	1.56 (2.33)

Note. [a]RT = response times in milliseconds. [b]EP = error percentages.

* = significantly different from adults at $p < .05$ by Dunnett's test (Kirk, 1968).

Table 1b

F Values from One-way ANOVAs Carried Out on Response Times and Error Percentages to Negative Priming Task Control Trial Displays for Age-defined Subgroups of Non-hyperactive Children in Experiment 1.

		Test of Between-Group Differences			
		Omnibus[a]	Linear[b] Term	Quadratic[b] Term	MSE
Spatial Location Task					
Primes	RT[c]	19.39**	52.26**	0.01	26128.89
	EP[d]	1.01	0.57	1.32	6.60
Probes	RT	20.72**	58.43**	0.19	20648.31
	EP	0.53	0.98	0.35	7.54
Letter Identity Task					
Primes	RT	27.29**	78.17**	0.46	131908.40
	EP	2.60	7.22**	0.52	10.18
Probes	RT	26.24**	76.73**	0.20	97179.14
	EP	1.89	4.65*	0.53	12.10

Note. [a]df = 3, 140. [b]df = 1, 140. [c]RT = response times. [d]EP = error percentages.

Statistical significance: * $p < .05$, ** $p < .01$.

quickly at the expense of high error percentages, particularly when responding to the probe displays. With regard to the low error percentages produced by the youngest subjects, this 'careful' responding may reflect a particularly vigorous, and somewhat naive, attempt on their part to comply with the instruction to try to make as few errors as possible. Being more sophisticated test-takers, the older children probably ascertained that a certain number of errors could be made without any significant negative consequences, and thus tried to minimize their response times at the expense of a few additional errors.

Ignored repetition effects. It was predicted that ignored repetition effects would not differ between age groups in the spatial location negative priming task, but that the youngest boys would show evidence of smaller ignored repetition effects in the letter identity task. Mean ignored repetition effects produced by the different age groups in the two tasks are shown in Figures 3a and 3b. The ignored repetition data were submitted to 2 x 5 (Task by Age Group) mixed ANOVAs. The predicted Age Group by Task interactions were not significant in either the response time or error rate analysis, nor were the Age Group main effects significant, all F's < 1.0. Task main effects were significant in both analyses, with overall ignored repetition effects of -39ms and -1.45% in the spatial location task, and -19ms and -0.13% in the letter identity task.

The results of the developmental analyses were only partly supportive of the previous findings by Tipper and his colleagues (Tipper et al., 1989; Tipper & McLaren, 1990). Consistent with Tipper and McLaren's study, no age-related differences in ignored repetition effects were found in the spatial location task in the present experiment. In the letter identity task, however, although the differences between the mean ignored repetition effects for the youngest group of boys and the adult subjects were in the expected direction, none of the age-related differences achieved statistical significance in between-group tests.

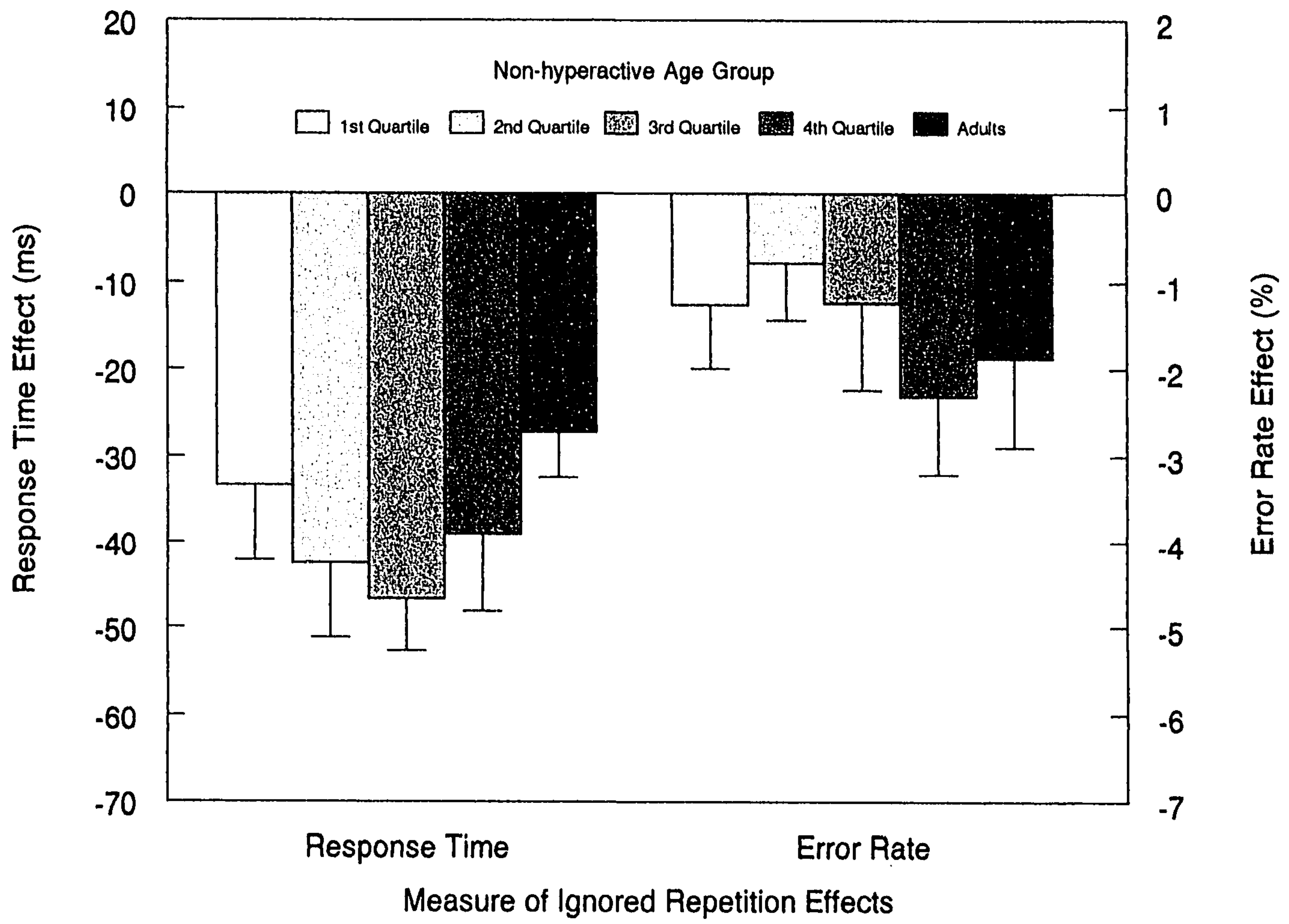

Figure 3a. Mean (+SE) ignored repetition effects in the spatial location negative priming task for adults and age-defined subgroups of non-hyperactive children.

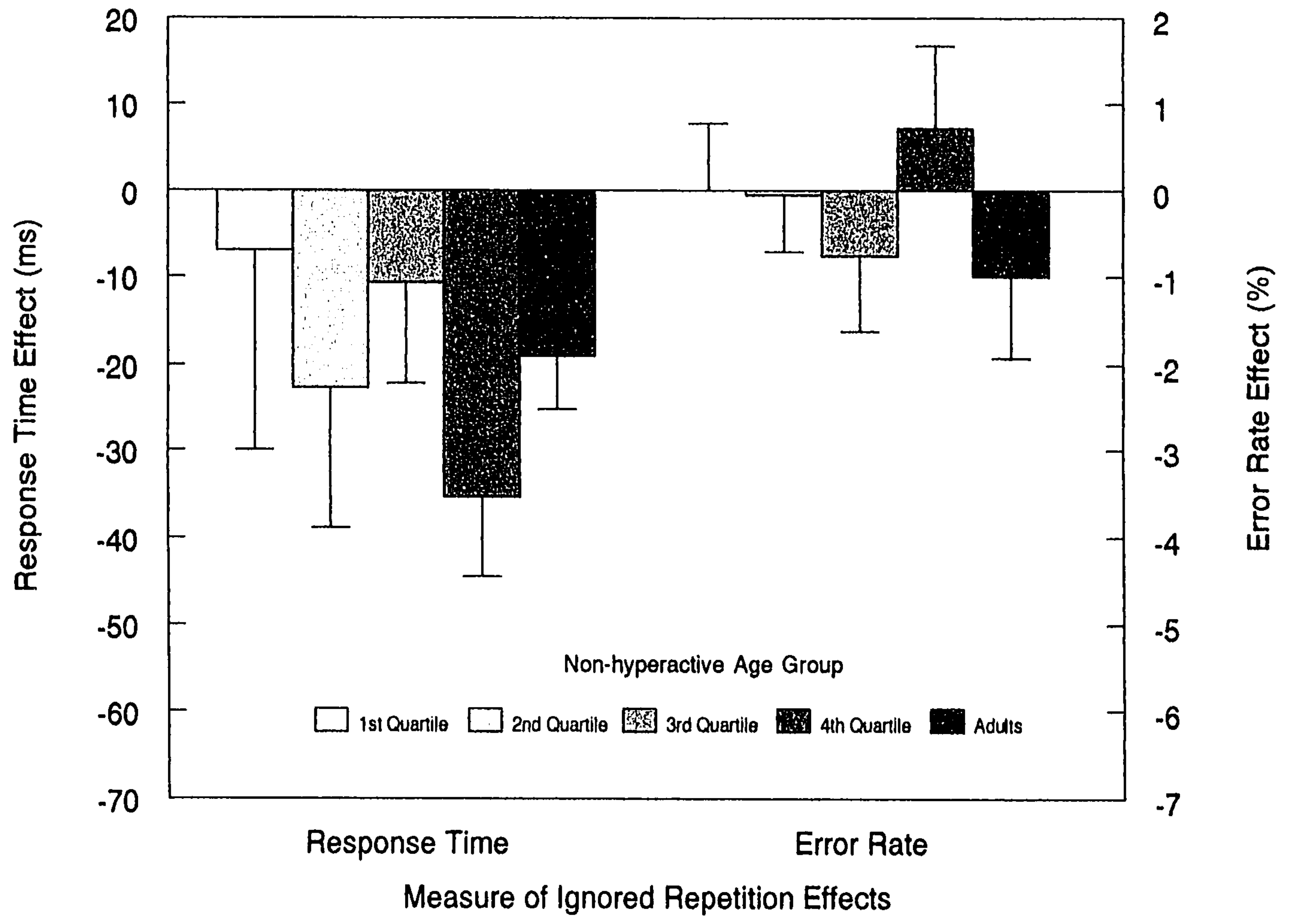

Figure 3b. Mean (+SE) ignored repetition effects in the letter identity negative priming task for adults and age-defined subgroups of non-hyperactive children.

An inspection of the response time data in Figure 3b provides a potential explanation for the lack of statistically significant age differences in the letter identity ignored repetition effects. As can be seen in the standard errors of the means, the between-subject variability in the ignored repetition effect produced by the youngest boys was large. Variability steadily declined, in both absolute terms and relative to the size of the ignored repetition effects, as the children became older.[4]

The extreme variability in the youngest group of children posed a problem for the hyperactive/non-hyperactive contrasts. If ignored repetition effects were not relatively stable in the control group of children, direct contrasts with children who were predicted to produce relatively smaller effects would be rendered ineffective. As a result, a decision was made to exclude children younger than eight years old from the hyperactive/non-hyperactive comparisons. By eliminating seven year-old children from further analysis, the variability in the control group due to age was reduced without reducing the power of the study to detect differences between hyperactive and non-hyperactive children.

Cartoon search task. Due to strict constraints on the duration of the experimental sessions with the children, not all subjects had time to carry out the cartoon search task. Data for two boys in the youngest quartile and five boys in the second quartile were unavailable for this reason. The mean search times for the remaining subjects in the age groups were submitted to a one-way ANOVA and are shown in Figure 4. The ANOVA was significant, $F(4, 150) = 6.32$, $MSE = 420.36$. Newman-Keuls post hoc tests revealed that the youngest boys were slower searchers than

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[4]A Bartlett-Box F homogeneity of variance test conducted on the response time measure of the ignored repetition effects for the letter identity task was significant, $F(4, 31077) = 15.4$, $p < .001$. Although the ANOVA F statistic is robust with regard to violations of the assumption of homogeneity of variances (Kirk, 1968), particularly when sample sizes are ≥ 7 (May, Masson, & Hunter, 1990), a nonparametric Kruskal-Wallis One-way ANOVA was carried out. This ANOVA did not reveal a statistically significant difference between the ignored repetition effects produced by the age groups, $\chi^2(4, N = 162) = 2.73$, $p > .60$.

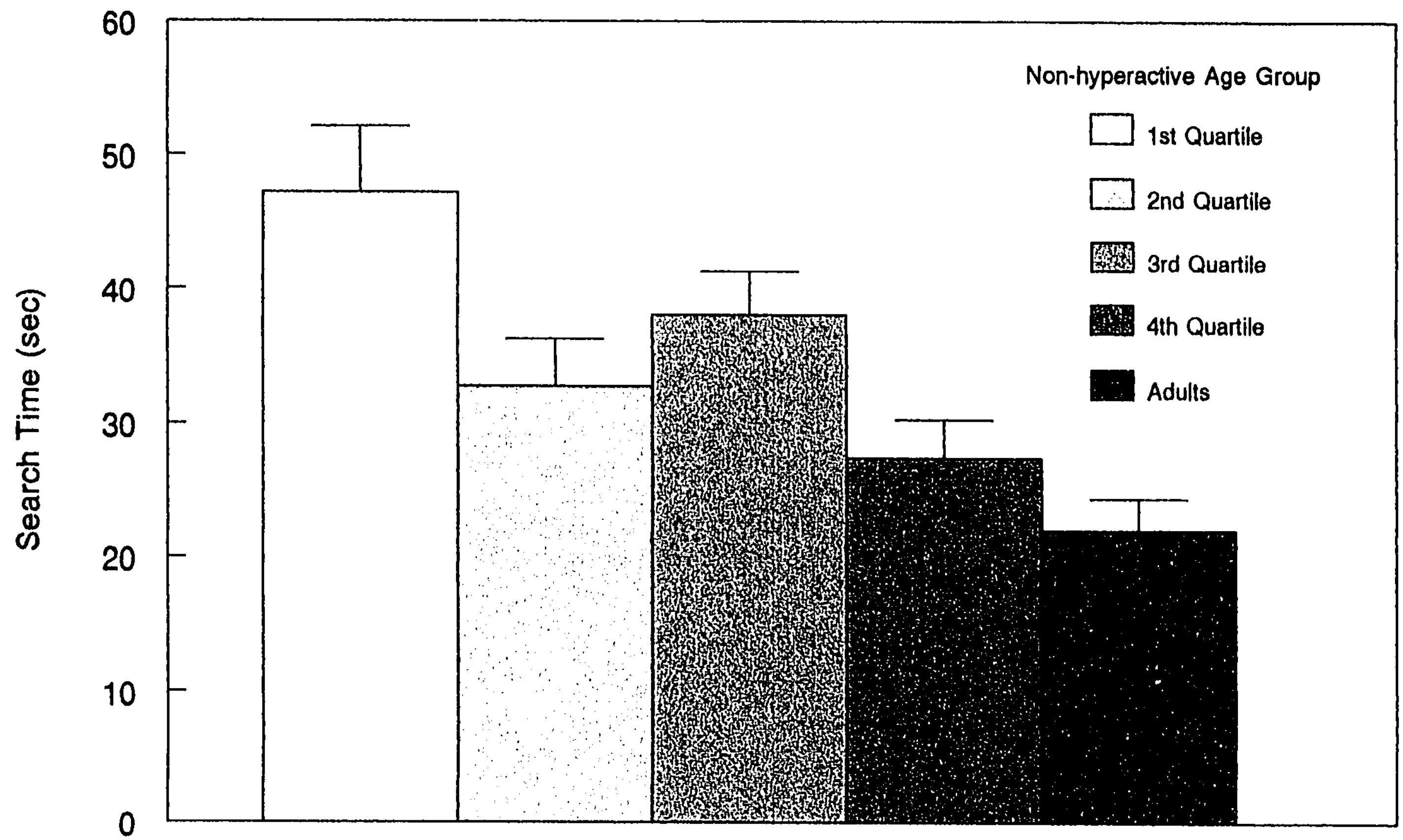

Figure 4. Mean (+SE) search times in the cartoon search task for adults and age-defined subgroups of non-hyperactive children.

the second and fourth quartiles of children and the adults, and that the third quartile of boys also were slower than the adults.

Hyperactive Analyses

After excluding boys younger than eight years old, data from 29 matched hyperactive/non-hyperactive pairs remained for statistical analysis. Mean ages, WRAT-R Reading scores, and parent and teacher reported Hyperactivity Index values for each group are presented in Table 2. A t-test performed on the WRAT-R scores revealed that despite the exclusion of reading impaired children there was still a significant difference between the reading abilities of the two groups, $t(28) = 2.22$. Because low reading scores on the WRAT-R have been linked to reduced ignored repetition effects in previous research (Tannock & Marriott, 1992), regressions between the reading scores and the ignored repetition effects in the present study were calculated. Neither the response time nor the error rate measure of the ignored repetition effects produced regressions that neared statistical significance (both t's < 0.5). Therefore, the reading scores were not considered further (Norman & Streiner, 1994).

Data from the hyperactive/non-hyperactive pairings were analyzed in the same manner as the developmental analyses reported above. Control trial responses and then ignored repetition effects from the two computer tasks are reported, followed by the cartoon search times.

Control trials. Means of median response times and mean error percentages generated by the hyperactive and non-hyperactive boys on the control trials in the two computerized tasks are shown in Figures 5a and 5b. The response times and error percentages were submitted to 2 x 2 ANOVAs that treated Group (matched pairs of hyperactive and non-hyperactive children) and Task (spatial location and letter identity) as repeated measures. The Task main effects in the prime and probe response time analyses both were significant, $F(1, 28) = 325.44$, MSE =

Table 2

Means and Standard Deviations for Descriptive Variables for Non-hyperactive and Hyperactive Groups in Experiment 1.

Descriptive Variable	Non-hyperactive M	Non-hyperactive SD	Hyperactive M	Hyperactive SD
Age[a]	9:9.1	0:8.5	9:8.7	0:8.4
WRAT-R Reading[b]	106.0	12.7	97.8	15.1
Parent Hyperactivity Index[c]	46.6	6.3	62.7	14.7
Teacher Hyperactivity Index[c]	46.0	6.3	65.3	9.2

Note. [a]years:months. [b]Norms: mean of 100, standard deviation of 15. [c]Norms: mean of 50, standard deviation of 10.

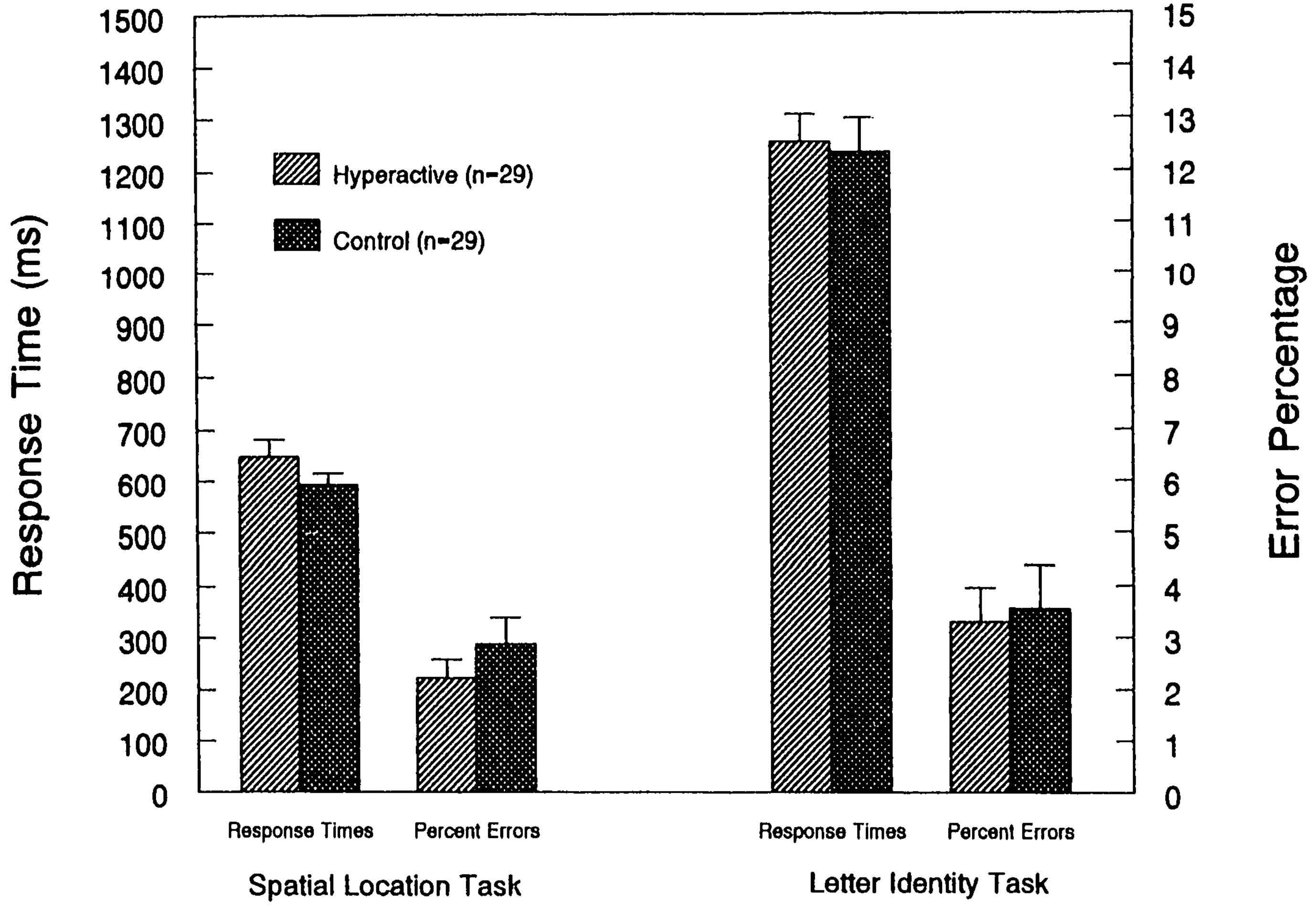

Figure 5a. Mean (+SE) response times and error percentages to control trial prime displays in the negative priming tasks for groups of hyperactive and matched control boys.

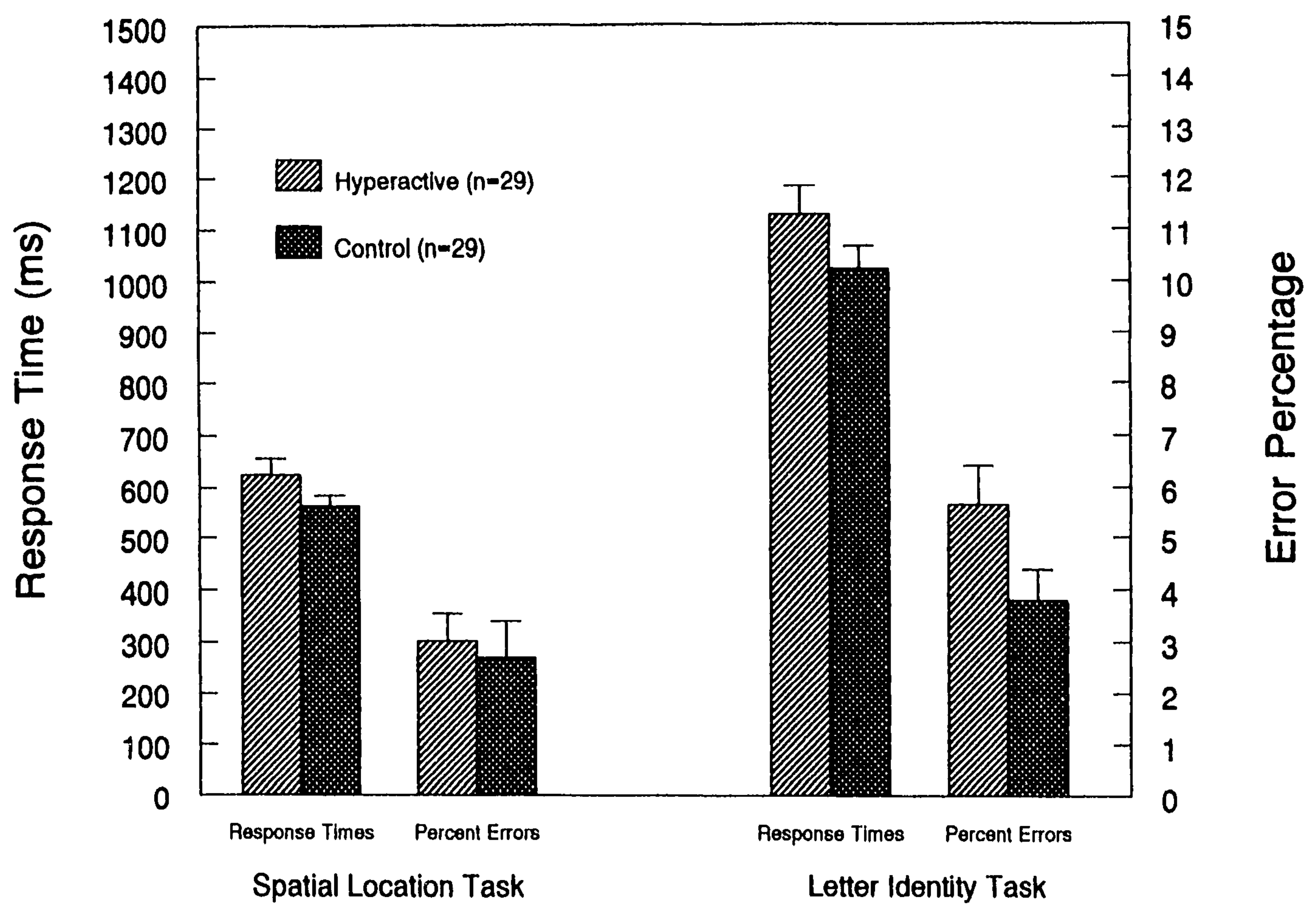

Figure 5b. Mean (+SE) response times and error percentages to control trial probe displays in the negative priming tasks for groups of hyperactive and matched control boys.

34747.21 and F(1, 28) = 315.00, MSE = 21342.19, respectively, with subjects slower to respond in the letter identity task. Neither of the main effects of Group, nor the Group by Task interactions, were significant. The ANOVAs carried out on the prime control trial error percentages revealed no significant main effects or interactions, and only the Task main effect was significant in the probe control trial error percentage analysis, F(1, 28) = 7.33, MSE = 13.77. More errors were made in the letter identity task than in the spatial location task.

Ignored repetition effects. It was predicted that hyperactive boys would produce smaller ignored repetition effects than their non-hyperactive counterparts, and that if a developmental delay interpretation of hyperactive inattention was correct, that the difference between the ignored repetition effects produced by the two groups would be larger in the letter identity task. The first step toward assessing these hypotheses was to demonstrate that the non-hyperactive control group of boys produced a statistically significant negative priming effect. Given the a priori prediction that normal children would be impaired in their responses to ignored repetition trials as compared to control trials, negative priming effects were expected to be unidirectional in nature. Accordingly, one-tailed t-tests against zero were carried out for each of the ignored repetition effects produced by the non-hyperactive boys. The ignored repetition effects produced in the response time measures for both the spatial location and letter identity tasks, and in the error rate measure in the spatial location task, were all significant, t's(28) = 7.00, 3.19, and 1.87, respectively. The ignored repetition effect produced in the letter identity task error rate measure was not statistically significant, t(28) = 0.99.

Differences in negative priming produced by hyperactive vs non-hyperactive boys were assessed using 2 x 2 (Group by Task) repeated measures ANOVAs carried out on the response time and error rate measures of the ignored repetition effects. Means of the median ignored repetition effects from the response time measures and means of the ignored repetition effects from the error rate measures are presented in Figure 6. Evidence that the hyperactive boys produced smaller ignored repetition effects than the non-hyperactive boys was found in a significant Group main effect in the analysis of the response time measure (hyperactives M = -29ms, non-hyperactives M = -48ms), $F(1, 28) = 3.35$, $MSE = 3224.54$. A non-significant Group by Task interaction, $F < 1.0$, was inconsistent with the developmental hypothesis. Neither the Group main effect nor the Group by Task interaction reached significance in the error rate analysis, $F(1, 28) < 1.0$, $MSE = 26.48$ and $F(1, 28) = 2.10$, $MSE = 25.09$, $p > .15$, respectively. The Task main effects in both analyses were significant (response time measure: $F(1, 28) = 4.22$, $MSE = 3554.96$; error rate measure: $F(1, 28) = 17.26$, $MSE = 10.74$), with larger ignored repetition effects being produced in the spatial location task.

The results of the between-group analyses of the response time ignored repetition effects in Experiment 1 did not indicate that either task was a better discriminator between hyperactive and non-hyperactive boys. However, an inspection of the combined pattern of response time and error rate ignored repetition effects for each task suggested that the letter identity task might have been a stronger test of the hypothesized reduction of ignored repetition effects in hyperactives.

To assess the relative merits of the letter identity and spatial location tasks as tests of hyperactive/non-hyperactive differences, a method of combining the response time and error rate ignored repetition effects was developed. Either of the response time and error rate effects produced by each subject could be negative (ignored repetition trials slower/less accurate than control trials) or positive (ignored repetition trials faster/more accurate).[5] Each child's pair of response time and error rate ignored repetition effects was 'scored' as '2 negatives', '1 negative', or '0 negatives'. The number of subjects in the hyperactive and non-hyperactive groups with each

[5]Error rate ignored repetition effects equal to zero were treated as positive for the purpose of this analysis.

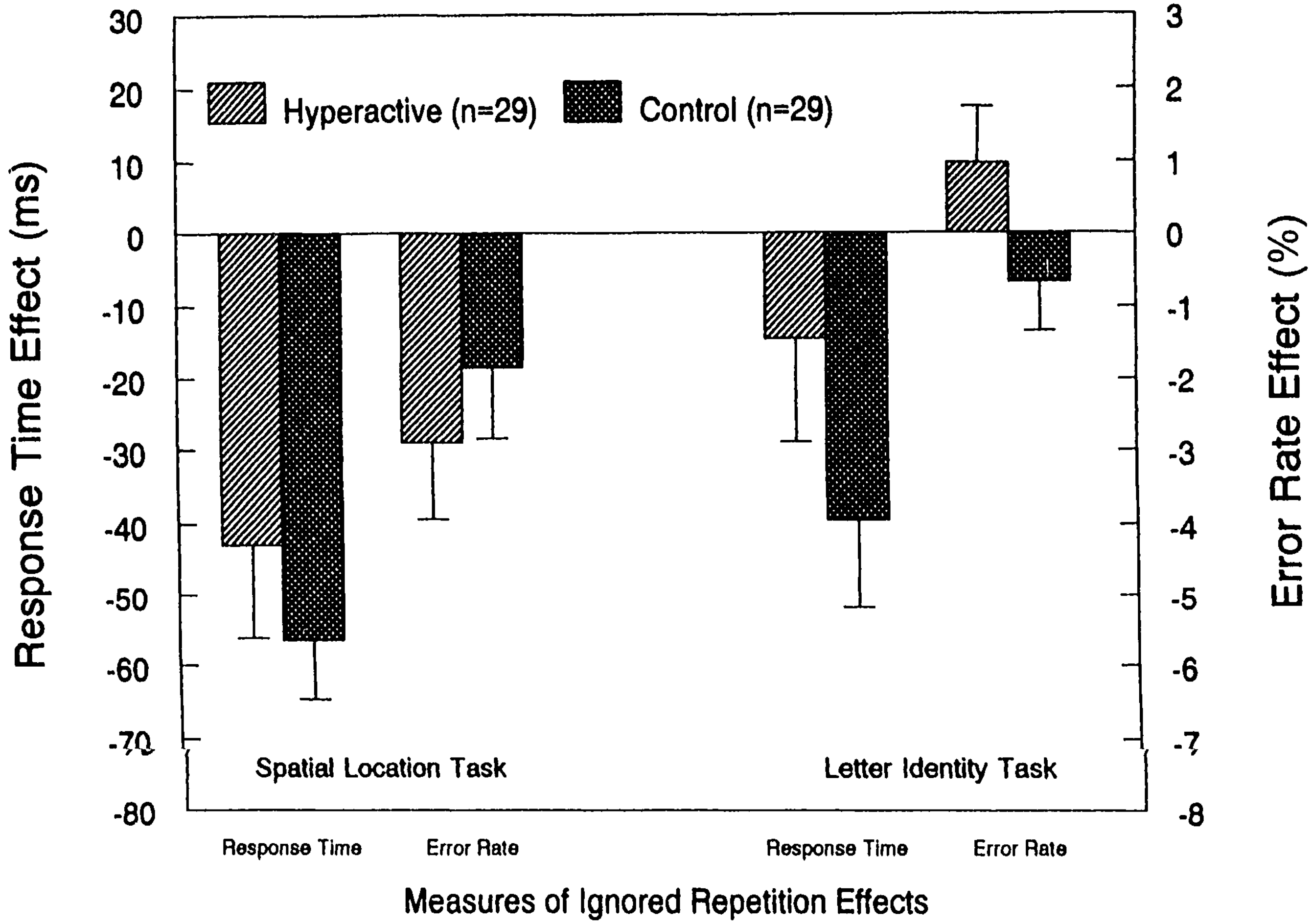

Figure 6. Mean (+SE) ignored repetition effects in the negative priming tasks for groups of hyperactive and matched control boys.

'score' then was entered into the 2 (Group) by 3 (2-, 1-, 0-Negative) configurations shown in Table 3, and was analyzed using χ^2. Although a significant result would not indicate exactly how the distribution of ignored repetition effects differed between the groups for a given task, at a minimum it would suggest that hyperactives and controls did not produce ignored repetition effects in a similar manner under the conditions present in that task. The χ^2 analyses conducted on the combined response time and error rate ignored repetition effects for the two tasks indicated that the letter identity task in fact was a better discriminator between hyperactive and non-hyperactive boys than the spatial location task, $\chi^2(2, N = 58) = 6.87$, $p < .05$ and $\chi^2(2, N = 58) = 0.50$, $p > .75$, for the letter identity and spatial location tasks respectively. The results of these analyses indicated that a letter identity task would be preferred over a spatial location task in research comparing negative priming produced by hyperactive and non-hyperactive children.

Cartoon search task. One hyperactive and one non-hyperactive boy did not complete the cartoon search task. Because they were not members of the same matched pair, two pairs of subjects were lost to the cartoon search task analysis. Mean search times for the remaining 27 hyperactive/non-hyperactive pairs were analyzed with a t-test. The difference between the search times was significant, $t(26) = 1.81$, indicating that the hyperactive children ($M = 35.6$ seconds, $SD = 18.3$) had more difficulty finding a target character in the distractor-filled pictures than did the non-hyperactive children ($M = 27.7$ seconds, $SD = 15.2$).

Discussion

Developmental Contrasts

The analyses of performance across the two negative priming tasks for the different age groups did not support the prediction that young children would show significantly smaller ignored repetition effects in an identity-based task. As predicted, there were no significant

Table 3

Frequency Counts of Subjects Producing Different Numbers of 'Negative' Ignored Repetition Effects for Non-hyperactive and Hyperactive Groups in Experiment 1.

	Number of Negative Ignored Repetition Effects per Subject		
	2	1	0
Spatial Location Task			
Non-hyperactive	11	16	2
Hyperactive	10	18	1
Letter Identity Task			
Non-hyperactive	10	17	2
Hyperactive	6	13	10

age-related differences in ignored repetition effects in the spatial location task, supporting the findings of Tipper and McLaren (1990). In the letter identity task, however, although mean ignored repetition effects for the youngest children were small, they were not statistically different from those produced by the older children and adults. A major factor in this null result was inordinately high between-subject variability in the younger groups of children. Other researchers have encountered comparable problems with similarly aged children, both in a letter search task (Gibson & Yonas, 1966), and in a negative priming study (McLaren, 1989).

The large between-subject variability for the seven year-olds in the letter identity task in Experiment 1 may indicate that these children were at a maturational cusp with regard to attentional processing of letters, with some boys demonstrating negative priming, and others not yet at that point developmentally. If this was the case, future letter identity negative priming research with children younger than those who participated in the present study should find even less evidence of ignored repetition effects, and reduced between-subject variability. Alternatively, it is possible that different stimuli would result in reliably smaller ignored repetition effects for seven year-olds when compared to their older peers.

The lack of significant age-related differences in ignored repetition effects among the non-hyperactive control subjects rendered the intended comparisons between hyperactive and young non-hyperactive children somewhat equivocal. As with the non-hyperactive developmental comparisons, the differences between negative priming produced by hyperactives and controls tended to be larger in the letter identity task than in the spatial location task, but the Group by Task interactions were not statistically significant. Future investigations that focus on similarities between hyperactive and young non-hyperactive children will need to use combinations of tasks and age ranges that generate larger and less variable age-related, and hyperactivity-related, differences between groups.

Hyperactive/Control Contrasts

The critical result from Experiment 1 was that hyperactive boys produced significantly smaller ignored repetition effects than age-matched non-hyperactive control children across two different negative priming tasks. According to the theoretical relationship between ignored repetition effects and selective attention put forward by Tipper and other researchers (Neill & Westberry, 1987; Tipper, 1985; Tipper et al., 1988), the present finding suggests that hyperactive children do not inhibit mental representations of distracting stimuli to the same degree as their non-hyperactive peers. It should be noted that the hyperactive children were not significantly slower or more error prone than the non-hyperactive children on the control trials in either negative priming task. This result emphasizes the importance of looking beyond baseline levels of performance in studies of selective attention and hyperactivity.

In addition to the results from the negative priming tasks, the hyperactive children in Experiment 1 were significantly slower than the non-hyperactives at locating target characters hidden among a distracting array of comical scenes and misleading patterns in the cartoon search task. These results could be interpreted as converging evidence that the ability of the hyperactive boys to inhibit their attention toward irrelevant stimuli was impaired. A finding of slower search times by hyperactive children for a target among distractors also is consistent with results from previous studies showing that hyperactive children are more responsive to the presence of distractors (Ceci & Tishman, 1984; Radosh & Gittelman, 1981; Rosenthal & Allen, 1980). Other studies that have failed to show excess distractibility in hyperactives may have chosen inadequate dependent measures (e.g., Barkley & Ullman, 1975; Dykman et al., 1979), or tasks in which selection of targets was not challenging enough to allow for central task interference from distractors (see Peters, 1977).

Limitations of hyperactive sampling in Experiment 1. The fact that differences between hyperactive and non-hyperactive children were revealed in Experiment 1 is particularly notable, given two significant limitations to the selection procedures used to determine the members of the hyperactive group of children. First, although the Conner's parent and teacher questionnaires that were used to assign group membership are widely accepted for identifying hyperactive subjects for research studies (e.g., Edelbrock & Rancurello, 1985; Silver, 1992), there is still a considerable possibility for bias and error in the completion of any self-administered rating scale. Parents may have wanted their children to appear as though they never behaved 'badly', lest it reflect on their parenting skills, and thus biased their ratings positively. Conversely, some parents may have given their children excessively negative ratings because they wanted to have their child identified as a behavior problem in the hopes that some form of therapy or special class at school might be offered.[6] Similarly, teachers may have biased their ratings positively for children they held in high regard, and negatively for other children whom they had previously decided were likely candidates for a hyperactivity diagnosis. In addition to problems of respondent bias, error can be introduced to questionnaire ratings due to the different inherent expectations of baseline 'appropriate' behavior that are applied by each parent and teacher. Although some researchers have defended parent and teacher questionnaire rating scales as suitably accurate indices of the behavior of hyperactive children (e.g., DuPaul, 1991; Schachar, Sandberg, & Rutter, 1986), other researchers have called attention to the often poor agreement found between behavior ratings drawn from questionnaire scales and actual behavior of children as observed by clinicians at school and in the home (e.g., Barkley, 1991; Rapoport & Benoit, 1975).

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[6]It should be reiterated that all parents were told that the purpose and consequence of the participation of their child would not extend beyond the research study itself.

One method of reducing the problems of bias that arise with the use of questionnaires as behavior rating instruments is to assess a child through interviews with the parents and teacher of the child. Schachar and his colleagues have developed and refined a pair of semi-structured interview protocols that facilitate the diagnosis of disruptive childhood behavior disorders based on information from parents and teachers (Schachar & Logan, 1990a, 1990b; Schachar & Tannock, 1995; Schachar, Tannock, Marriott, & Logan, 1995; Tannock, Ickowicz, & Schachar, 1995; Tannock & Schachar, 1992; Tannock, Schachar, & Logan, 1993, 1995). These interview protocols focus on gaining descriptions of the behavior of a child in a variety of situations, and then having a clinician-interviewer, rather than the parents or teacher, rate the presence or absence of a behavior problem. By having a clinician rate the behaviors, a consistent baseline definition of appropriate behavior is applied. Also, the interview allows the clinician to probe specific descriptions of behavior to help reduce the effects of respondent bias. In Experiment 2 of the present study, rather than questionnaires, the semi-structured interviews developed by Schachar and his colleagues were used to identify hyperactive children. It was expected that this procedural change would increase significantly the accuracy of the discrimination between hyperactive and non-hyperactive subjects and thus provide a clearer view of any apparent differences between the two groups of children.

A second limitation of the subject selection procedure used in Experiment 1 was that children being treated with methylphenidate were excluded from the hyperactive sample. In all likelihood, this subgroup of hyperactive children were, on average, more disabled than the sample that was included in the study, and as such their exclusion may have reduced any differences between the hyperactive and control groups. In Experiment 2, hyperactive children on methylphenidate were taken off their medication for the purpose of the study, thus creating a more representative sample of hyperactive boys than was available in Experiment 1.

Experiment 2

The primary purpose of Experiment 2 was to verify the difference in ignored repetition effects between hyperactive and non-hyperactive boys that was observed in Experiment 1. A letter identity negative priming task similar to the one used in the previous experiment was employed. Experiment 2 differed from Experiment 1 in that the hyperactive subjects were formally diagnosed with ADHD based on interviews with parents and teachers. Also, hyperactive boys in Experiment 2 who were taking methylphenidate to treat their disorder, and who therefore could be argued to be the most severely disordered children, were included in the study after interrupting their medication regimen. It was believed that a particularly strong test of the hypothesis that hyperactivity and reduced ignored repetition effects are associated would be achieved by focussing on a letter identity negative priming task, and by contrasting non-hyperactive control subjects with boys whose overactivity and inattention was severe enough to warrant a clinical diagnosis of ADHD.

Experiment 2 also included a measure of the impact of distractor related responses on responses to target stimuli. Tipper and his colleagues have shown that interference arises when an accompanying distracting stimulus is associated with a response that is contrary to the task-relevant response (Driver & Tipper, 1989; Tipper & Baylis, 1987; Tipper et al., 1988). Other researchers have studied this 'response incompatibility' interference extensively in the form of the STROOP color-word effect (e.g., naming the color of the word "blue" written in red ink; Stroop, 1935; see MacLeod, 1991, for a comprehensive review), and as "Eriksen" interference (responding to a target letter that is flanked by distractor letters that are associated with a different response; Eriksen & Eriksen, 1974; Eriksen, Eriksen, & Hoffman, 1986; Eriksen & Hoffman, 1973; Eriksen & Schultz, 1979).

Numerous studies have shown hyperactive children to be worse than normal control children at controlling their responding, both to irrelevant stimuli and when reacting to changes in relevant stimuli. For example, hyperactive children produce larger Stroop interference effects than non-hyperactive children (Barkley et al., 1992; Boucugnani & Jones, 1989; Carter et al., 1995; Gorenstein et al., 1989). Other researchers have reported that hyperactive children are worse than normal control children at withholding their responding upon hearing the 'stop' signal in a Go/No-Go task (Schachar & Logan, 1990b; Schachar et al., 1995; Shue & Douglas, 1992; Trommer, Hoeppner, Lorber, & Armstrong, 1988). Experiment 2 of the present study examined the issue of control of responses in hyperactive children by including measures of Eriksen response incompatibility interference. Based on the previous findings of poor response control in hyperactive children, it was predicted that the hyperactive boys in Experiment 2 would show greater interference than their non-hyperactive counterparts from the responses associated with the distractors in the stimulus displays.

Method

Subjects

The hyperactive and control subjects were chosen from a sample of 107 boys who had been seen in the outpatient departments of Psychiatry or Pediatrics at The Hospital for Sick Children, Toronto. The hyperactive boys had been referred for assessment of disruptive behavior, whereas the non-hyperactive controls had been seen for uncomplicated, non-psychiatric medical problems. Six children were excluded from the present study: one boy due to incomplete behavioral ratings; two others because their estimated Full Scale IQs were below 80;[7] and three

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[7]As part of a larger series of investigations with this sample of subjects, each child was assessed using the Vocabulary and Block Design subtests from the WISC-R (Wechsler, 1974), and full scale IQs were estimated.

other boys because they did not complete the necessary experimental session. Data from 25 of the remaining subjects were excluded from all analyses: for 22 boys because they demonstrated serious reading problems on the WRAT-R Reading subtest (greater than 1.5 SD below age-base norms); and for 3 others because it was uncovered during their behavioral assessments that they were suffering from extreme emotional difficulties. Of the remaining 76 subjects, 46 were identified as hyperactive and 30 as non-hyperactive based on behavioral ratings gained from parents and teachers (see *Hyperactivity Assessment* below). All subjects were taking part in a larger series of investigations distributed across two experimental sessions.

Hyperactivity Assessment

The children's behavior at home was assessed via an in-person, semi-structured interview with one or both parents. The interview protocol (Parent Interview for Child Symptoms: PICS) elicits descriptions of children's actual behavior in a variety of settings, and symptomatology in each setting is rated by a trained interviewer on a scale of zero (no symptom) to three (severe symptom) according to pre-set criteria (based on extent of disability and age-appropriateness). For the purpose of diagnosis, a given symptom was scored as being present if a rating of 2 or 3 was assessed. Consistent with the recommendations for applying Attention-deficit Hyperactivity Disorder (ADHD) diagnoses as presented in DSM-III-R (American Psychiatric Association, 1987), a child was categorized as hyperactive if at least 8 of a maximum of 14 possible symptoms were judged to be present.

A modified version of the PICS was used to conduct semi-structured telephone interviews with the children's teachers (Teacher Telephone Interview: TTI). Symptoms at school, and subsequent diagnostic categorization, were assessed in the same manner as was done for behavior in the home. Boys who exhibited fewer than 8 hyperactive symptoms in both the home and school contexts were categorized as non-hyperactive. Both the PICS and TTI have been used successfully for the categorization of children in several previous hyperactivity studies (Schachar & Logan, 1990a, 1990b; Schachar & Tannock, 1995; Schachar et al., 1995; Tannock, Ickowicz, & Schachar, 1995; Tannock & Schachar, 1992; Tannock, Schachar, & Logan, 1993, 1995).

Letter Identity Negative Priming Task

Materials. The negative priming task that was used in Experiment 2 involved slightly different stimuli and task demands than the letter identity task that was used in Experiment 1. The stimulus letters were 4 uppercase consonants: M, W, H, and N. These letters were selected because of the high degree of overlap in their physical properties. Each stimulus display was presented as a row of three letters side-by-side, with the end letters being identical to each other, and different from the center letter. As in Experiment 1, the video screen image of each letter was 4mm wide and 6 mm high, and when viewed from a distance of 1 meter, each letter subtended 0.23 by 0.34 degrees of visual angle, the space between adjacent letters was 0.06 degrees, and the edge-to-edge width of a three letter group was 0.81 degrees.

Design. The letters were grouped into two pairs, 'M,W' and 'H,N', and were assigned respectively to the leftmost and rightmost buttons on a response box, with labels displaying the letter pairs attached directly above the buttons. Subjects were instructed to press the button that corresponded to the middle letter in each three letter display.

The general organization of the task was identical to that of the negative priming tasks in Experiment 1. On every trial subjects saw and responded to prime and probe letter strings in sequence, and on ignored repetition trials the distractor letter in the prime became the target letter in the probe. Each ignored repetition trial was paired with a matched control trial that had the same probe letter string, but differed in that there was no overlap between the particular letters in the prime and probe. The ignored repetition/control trials were matched regarding the combination of responses to the prime and probe trigrams (left button then right, right then left, left-left, & right-right), and whether the target and distractor **within** the prime trigram were associated with the same or different response button.

The pairs of trigrams were presented as a series of 9 blocks of 29 pairs. Each block contained three ignored repetition trials along with their control trials. The remaining 23 trials in each block were comprised of a mixture of control trials along with trials containing other relationships between prime and probe letters (see Appendix A for details of other trial types). These trials were not pertinent to the present study and hence were treated as filler trials.

The first trial of each block was a filler trial, used as a buffer against first-trial errors. With the exception of the first trial, the trials in each block were randomly ordered with the constraint that two instances of the same trigram were separated by presentations of at least two other trials. The same ordering of trials was used for all subjects. Although the first block of trials had the same format as the others, it was treated as a practice block and did not contribute to the analyzed data. Calculation of ignored repetition effects was carried out in exactly the same manner as in Experiment 1.

Calculation of Response Incompatibility Effects. The stimulus-response mappings created two categories of trigram stimuli: 'compatible' trials were those for which the button associated with the center letter matched that associated with the flanking letters; 'incompatible' trials were those for which the center and flanking letters were mapped onto separate response buttons. The response incompatibility effect was calculated for each subject based on responses to prime presentations only. Median correct response times for compatible trigrams were subtracted from those for incompatible trigrams.[8] The effect on error rates was calculated in the same manner, substituting percentage errors for response times. The calculations were designed so that response interference would be represented by positive values.

Procedure. The negative priming task was conducted using the same type of Apple IIe computer and green monochrome video monitor as was used in Experiment 1, but millisecond response times were measured using a Cognitive Testing Station (Digitry Company) hardware/software system. The testing procedure was identical to that used in the letter identity task in Experiment 1, with three exceptions: the READY signal was followed by four asterisks in a diamond configuration framing the middle of the computer screen; the prime and probe displays self-terminated after 4000 milliseconds if no response had been made; and the probe response was followed first by a 1500 millisecond blank screen and then by the READY signal for the next trial. Treatment of early button presses was the same as in Experiment 1.

The task was explained using pictures of example trigrams, to which the children had to demonstrate appropriate responses. The final instruction given before the start of the task emphasized that responses should be made quickly, but that it was of primary importance to make as few errors as possible.

At the end of each block of trials subjects were given feedback on the computer screen. If errors had been made on five or fewer trigrams then the subject was prompted to "Please keep responding quickly". The message was reiterated by the experimenter with a warning to continue

[8]There were two incompatible and one compatible letter combinations for each of the four possible target letters. For a given target letter, the median response time for the compatible trigram was subtracted from the average of the values from the two incompatible trigrams

$$\text{e.g.,} \quad \frac{(RT_{\text{'HMH'}} + RT_{\text{'NMN'}})}{2} - RT_{\text{'WMW'}}$$

This procedure was repeated for each of the four target letters, and then the four resulting differences were averaged to gain a single measure of the response time incompatibility effect.

to make very few errors. If six or more trigrams were responded to incorrectly then the message read "You are making too many errors. Please try to be more careful". The computer's message was reinforced by the experimenter and the child was advised to take more time before responding if necessary. The children were given brief rests between blocks, and after the fifth block a message on the computer screen instructed the subjects to take a slightly longer (approximately five minute) break. The entire task required 50 to 60 minutes to complete.

Session Format

The computer task was conducted at the beginning of the second research session involving the experimenter and each child. The Reading subtest of the WRAT-R and the Block Design and Vocabulary subtests of the WISC-R, along with a different experimental computer task, were conducted during the first research session several days to a few weeks earlier.

Results

Statistical Methods

Methods for analyzing control trial responses and ignored repetition effects, and critical levels of significance, were identical to those used in Experiment 1. Significance levels for analyses of response incompatibility effects were set at $p < .05$, two-tailed. Unlike Experiment 1, independent sample t-tests were used for all hyperactive/non-hyperactive comparisons.

Developmental Analyses

Due to the small number of non-hyperactive control subjects, age-related differences in ignored repetition effects were not a primary concern in Experiment 2. However, in an attempt to clarify the developmental findings from Experiment 1, the non-hyperactive children were divided into 5 groups according to their year of birth so that developmental analyses similar to those in Experiment 1 could be conducted. Mean ages (years:months) for each subgroup were 7:2, 8:5, 9:5, 10:4, and 11:5. The numbers of subjects in each age group were 5, 8, 8, 5, and 4 for the 7 to 11 year-olds, respectively. Median correct response times and mean error percentages for responses to the prime and probe control trial displays were compared across the age groups. Following this analysis, error rate and response time ignored repetition and response incompatibility effects were analyzed across all age groups.

Control trials. Response times and error percentages from the prime and probe control trials are shown in Table 4a. The results of one-way ANOVAs carried out on the response time and error percentage data are presented in Table 4b. All but one of the omnibus F values were statistically significant. The analyses of the polynomial components revealed significant linear components for the response times and a significant quadratic component for the error percentages to the probe displays. The quadratic component for the analysis of the prime display error percentages approached significance, $p < .08$.

The developmental pattern of steadily decreasing response times, and error percentages that increase and then decrease with the oldest age group (11 year-olds in Experiment 2 and university undergraduates in Experiment 1), is analogous to that found in Experiment 1. The results of the control trial analyses indicate that the sample of non-hyperactive control subjects used in Experiment 2 was comparable with the sample from the previous experiment.

Ignored repetition effects. It was predicted in Experiment 1 that ignored repetition effects produced by young boys in a letter identity task would be smaller than those shown by their older peers. This hypothesis was not confirmed statistically in the previous experiment, due in part to very large between-subject variability among the youngest subjects. Experiment 2 provided for a second, albeit less powerful, test of this hypothesis. Mean ignored repetition effects produced by

Table 4a

Mean (Standard Deviation) Response Times and Error Percentages to Negative Priming Task Control Trial Displays for Age-defined Subgroups of Non-hyperactive Children in Experiment 2.

		Age-defined Subgroup of Non-hyperactive Children				
		7 year-olds	8 year-olds	9 year-olds	10 year-olds	11 year-olds
Primes	RT[a]	1437 (294)	1122 (196)	1136 (224)	893 (347)	785 (88)
	EP[b]	4.01 (1.93)	7.08 (4.13)	6.16 (4.49)	7.59 (6.80)	3.01 (1.52)
Probes	RT	1318 (129)	1041 (96)	1129 (289)	802 (226)	740 (100)
	EP	1.74 (1.66)	6.96 (2.81)	4.52 (2.69)	6.24 (4.35)	3.05 (3.26)

Note. [a]RT = response times in milliseconds. [b]EP = error percentages.

Table 4b

F Values from One-way ANOVAs Carried Out on Response Times and Error Percentages to Negative Priming Task Control Trial Displays for Age-defined Subgroups of Non-hyperactive Children in Experiment 2.

		Test of Between-Group Differences			
		Omnibus[a]	Linear[b] Term	Quadratic[b] Term	MSE
Primes	RT[c]	5.06**	18.76**	0.16	59012.59
	EP[d]	1.03	0.05	3.41	18.70
Probes	RT	7.17**	24.10**	0.00	37954.44
	EP	3.00*	0.19	6.80*	8.98

Note. [a]df = 4, 25. [b]df = 1, 25. [c]RT = response times. [d]EP = error percentages.

Statistical significance: * $p < .05$, ** $p < .01$.

the different age groups in Experiment 2 are shown in Figure 7. As in Experiment 1, the between-subject variability of the response time ignored repetition effects produced by the youngest group of subjects was considerably larger than that of the older children. Given the small sample sizes, this violation of the assumption of the homogeneity of variances was beyond the accepted limits of the robustness of the F statistic (May et al., 1990), and therefore nonparametric Kruskal-Wallis one-way ANOVAs were used to analyze the ignored repetition data. Neither the ANOVA on the response time measure, $\chi^2(4, N = 30) = 5.71$, nor the ANOVA on the error rate measure, $\chi^2(4, N = 30) = 3.29$, neared statistical significance, both p values > .20.

As in Experiment 1, the results of the developmental analyses in Experiment 2 were consistent in direction with previous findings by Tipper et al., (1989). Taken together, the developmental findings from Experiments 1 and 2 of the present study are not inconsistent with the view that boys around the age of seven years are at a maturational cusp with regard to negative priming in identification tasks.

Response incompatibility effects. The response incompatibility effects produced by the non-hyperactive children are shown in Figure 8. One-way ANOVAs carried out on the data did not reveal significant age-related differences in response incompatibility effects in the response time measure, $F(4, 25) = 0.69$, $MSE = 3060.11$, although the analysis of the data from the error rate measure did approach significance, $F(4, 25) = 2.25$, $MSE = 3060.11$, $p < .10$.

Hyperactive Analyses

To remain consistent with the age range used for the sample in Experiment 1, boys younger than eight years old were excluded from the hyperactive/non-hyperactive contrasts in Experiment 2. The removal of the seven year-olds from the analyses resulted in samples of 38 hyperactive and 25 non-hyperactive children. Mean ages, estimated FSIQs, WRAT-R Reading

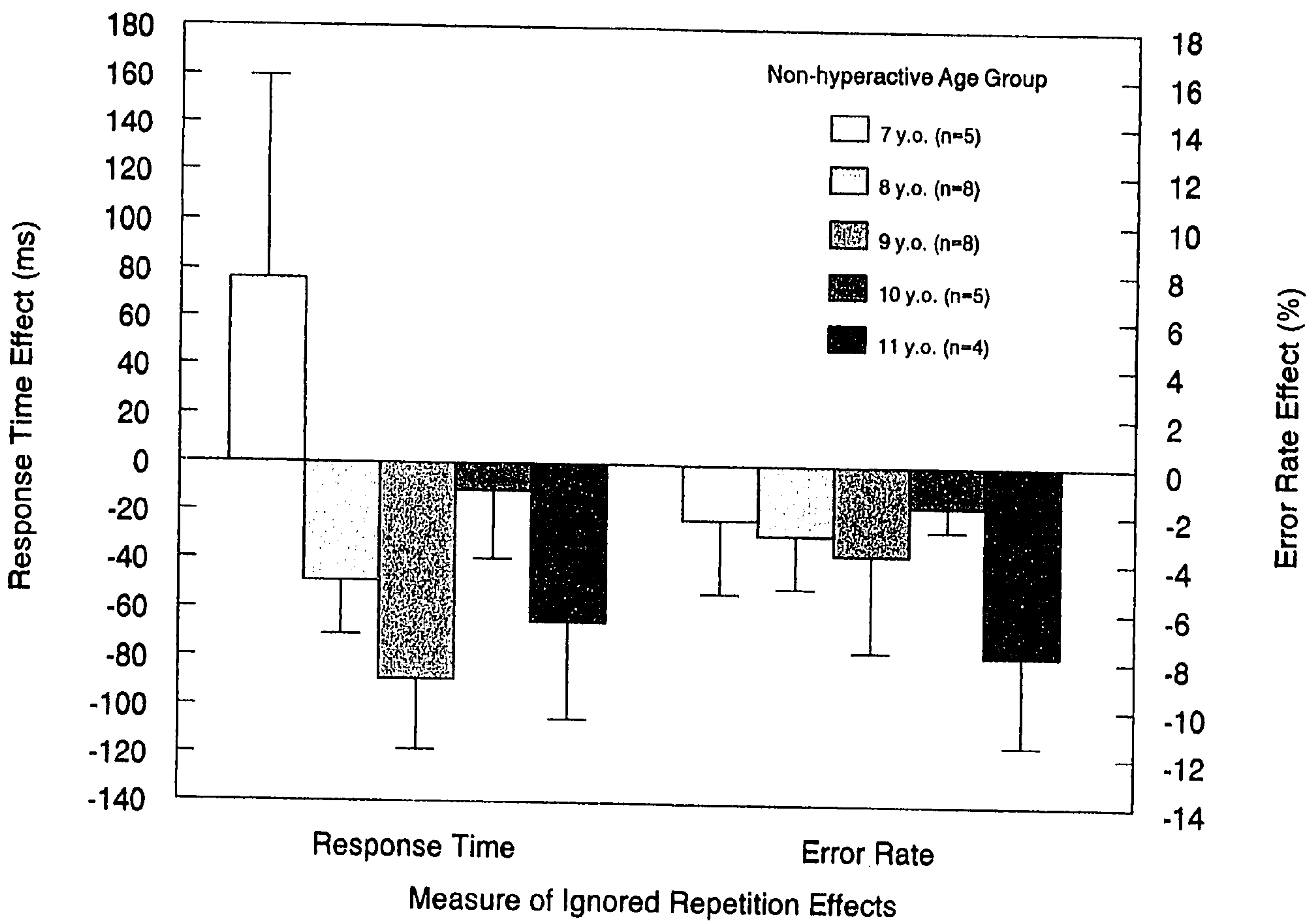

Figure 7. Mean (+SE) ignored repetition effects for age-defined subgroups of non-hyperactive children.

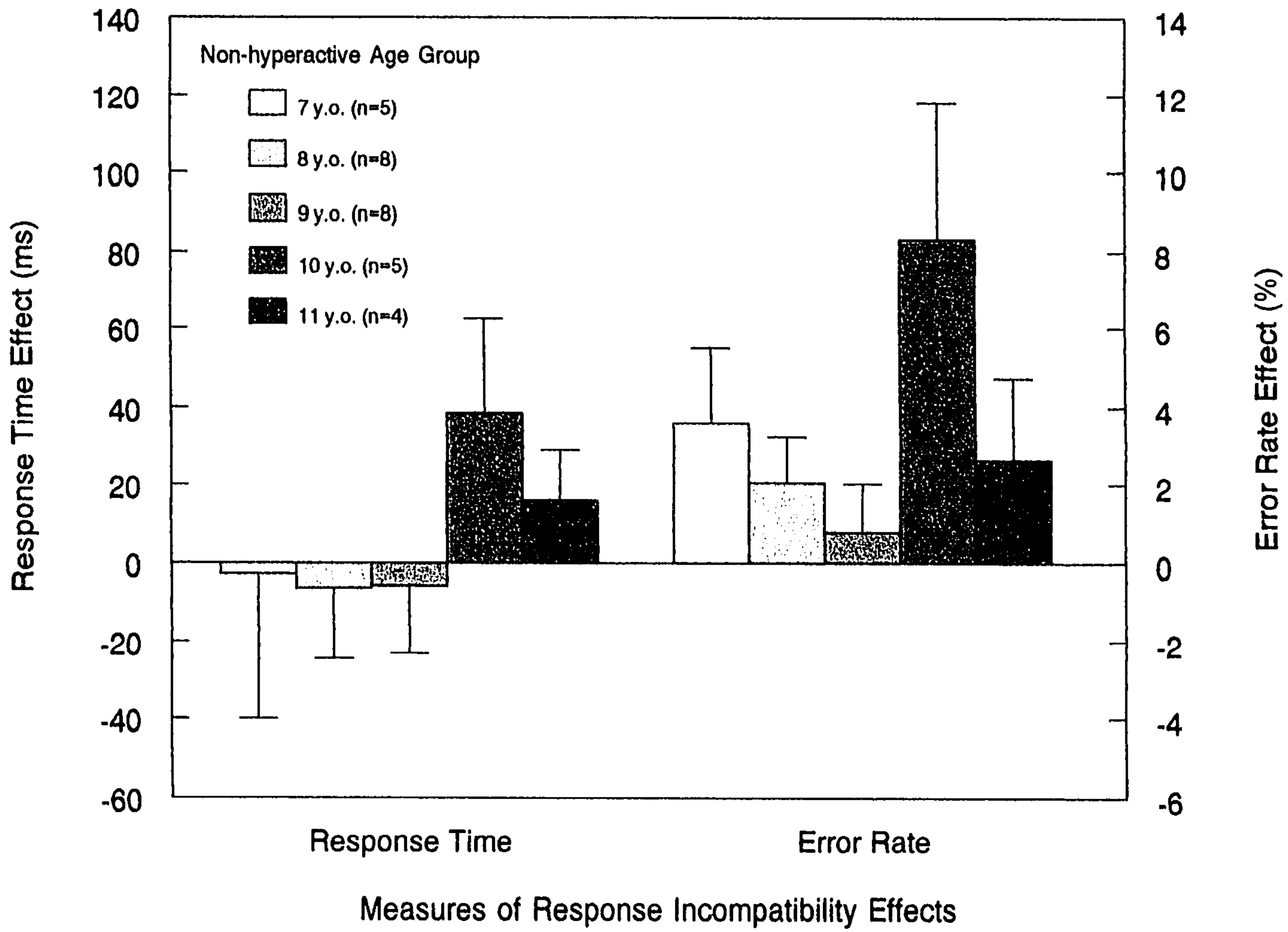

Figure 8. Mean (+SE) response incompatibility effects for age-defined subgroups of non-hyperactive children.

scores, and parent- and teacher-identified ADHD symptoms for each group are presented in Table 5. T-tests performed on the ages of the groups, as well as on FSIQ and WRAT-R scores did not reveal any significant differences between the two groups (all p values $> .20$).

Analyses contrasting the hyperactive and non-hyperactive groups were carried out in the same manner as the analysis of the non-hyperactive developmental data reported above: analyses of control trial responses, ignored repetition effects, and response incompatibility effects are presented in turn.

Control trials. Means of median response times and mean error percentages produced by the hyperactive and non-hyperactive boys on the control trials are shown in Figure 9. Between-group t-tests of the response times and error percentages to the prime and probe displays revealed that the hyperactive children were significantly slower to respond to the primes, $t(61) = 2.39$, but they also tended to make fewer errors than the non-hyperactive boys with these displays, $t(61) = 1.68$, $p < .10$. The hyperactive subjects also were significantly slower than the non-hyperactive children to respond to the probe displays, $t(61) = 2.27$, but no reciprocal difference in error percentages between the two groups was found, $t(61) < .10$.

Ignored repetition effects. As in Experiment 1, the hyperactive boys were expected to produce smaller ignored repetition effects than the non-hyperactive boys. Means of the median response time ignored repetition effects and means of the error rate ignored repetition effects for the two groups are shown in Figure 10. One-tailed t-tests against zero of the ignored repetition effects produced by the non-hyperactive control boys were significant for the response time measure, $t(24) = 3.91$, and for the error rate measure, $t(24) = 2.42$. A between-group t-test of the response time ignored repetition effects did not reveal a significant difference between the hyperactive and non-hyperactive boys, $t(61) = 1.04$, $p > .15$. However, a between-group t-test of the error rate ignored repetition effects approached statistical significance, $t(61) = 1.51$, $p < .07$.

Table 5

Means and Standard Deviations for Descriptive Variables for Non-hyperactive and Hyperactive Groups in Experiment 2.

	Non-hyperactive		Hyperactive	
Descriptive Variable	M	SD	M	SD
Age[a]	9:8.3	1:1.6	9:7.9	1:1.5
Estimated FSIQ[b]	110.4	14.0	106.4	14.1
WRAT-R Reading[c]	103.8	15.3	99.3	12.0
Parent-identified ADHD Symptoms[d]	2.48	1.92	8.76	3.48
Teacher-identified ADHD Symptoms[d]	2.16	2.54	9.45	3.69

Note. [a]years:months. [b]Full Scale IQ norms: mean of 100, standard deviation of 15. [c]Norms: mean of 100, standard deviation of 15. [d]Because 8 or more symptoms identified by *either* informant resulted in an ADHD diagnosis, some hyperactive boys received low symptom counts in one context.

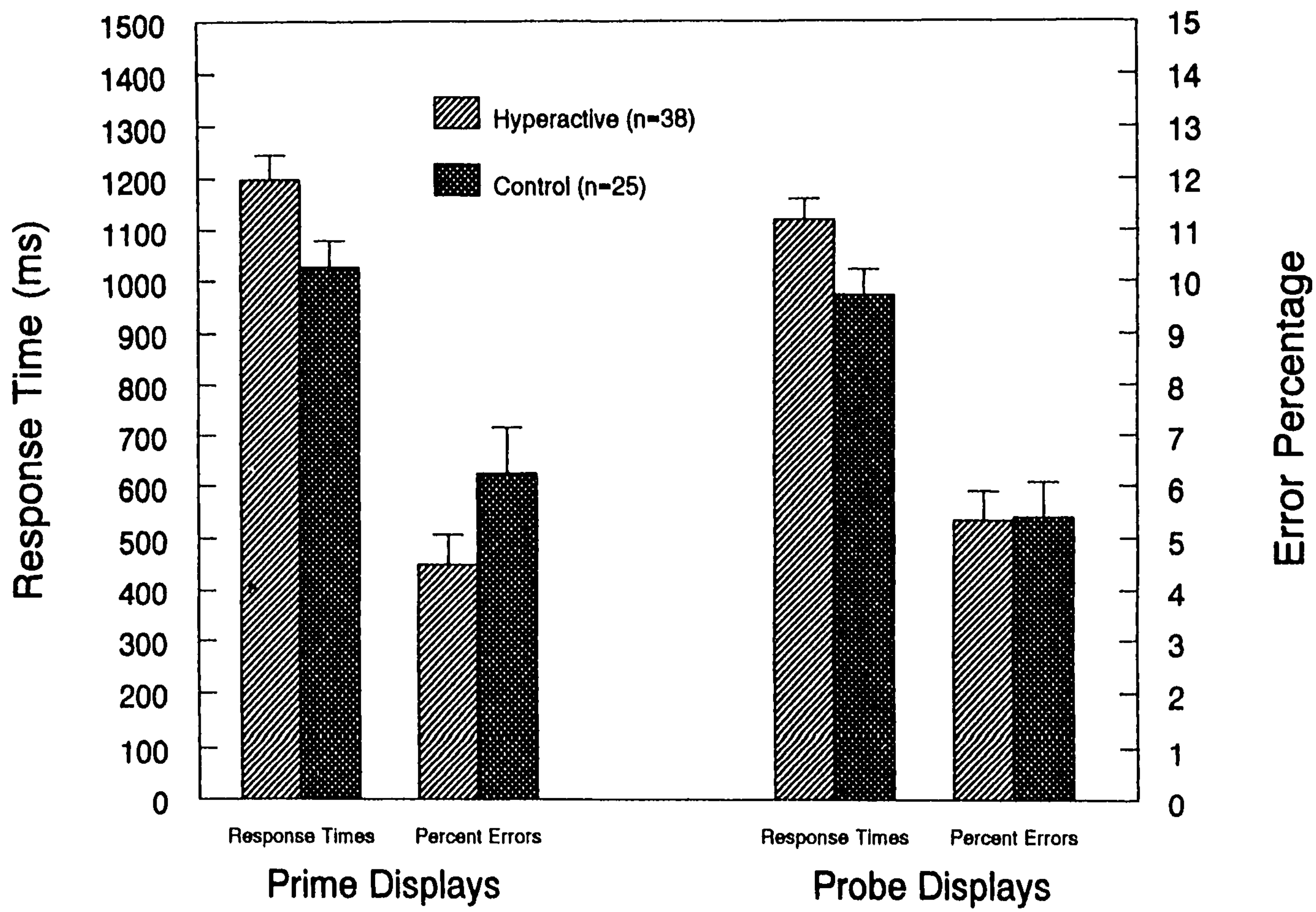

Figure 9. Mean (+SE) response times and error percentages to control trial displays in the negative priming task for groups of hyperactive and control boys.

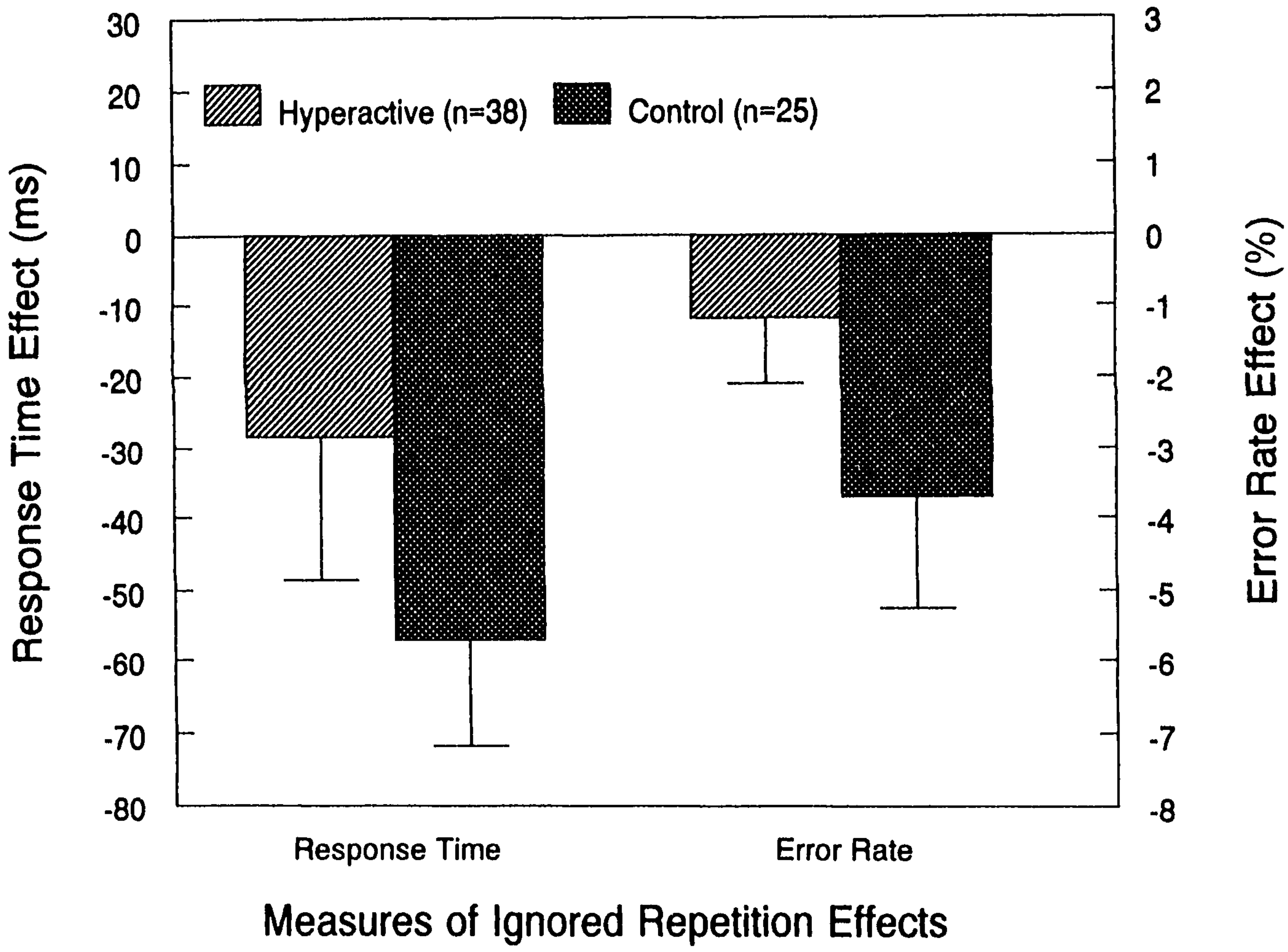

Figure 10. Mean (+SE) ignored repetition effects in the negative priming task for groups of hyperactive and control boys.

Response incompatibility effects. The response incompatibility effects produced by the hyperactive and non-hyperactive groups are presented in Figure 11. As with the ignored repetition effect analyses, the response incompatibility effects produced by the non-hyperactive control boys were first tested against zero. The results of the t-tests against zero showed that the error rate measure was significant, $t(24) = 2.88$, but the response time measure did not approach significance, $t(24) = 0.66$. A between-group t-test of the response time response incompatibility effects indicated no significant difference between the hyperactive and non-hyperactive boys, $t(61) < .20$. A between-group t-test of the data from the error rate measure neared significance, $t(61) = 1.93$, $p < .06$, but contrary to expectations, the non-hyperactive boys showed the larger response incompatibility effect.

It had been expected that the hyperactive children would be particularly susceptible to the influence of the responses associated with the distractors, based on the results of other research linking hyperactive subjects with demonstrations of poor response control. However, the manipulation of compatible versus incompatible distractor responses that was applied in Experiment 2 did not result in interference effects with the hyperactive and non-hyperactive children in the same manner as has been observed with normal adult subjects in previous studies (Eriksen & Eriksen, 1974; Eriksen & Hoffman, 1973; Eriksen & Schultz, 1979; Eriksen et al., 1986).

Discussion

Although the differences between the ignored repetition effects produced by the hyperactive and non-hyperactive subjects were in the predicted direction in both the response time and error rate measures, neither difference was statistically significant, suggesting that Experiment 2 may simply have lacked sufficient power. Given the apparent distribution of

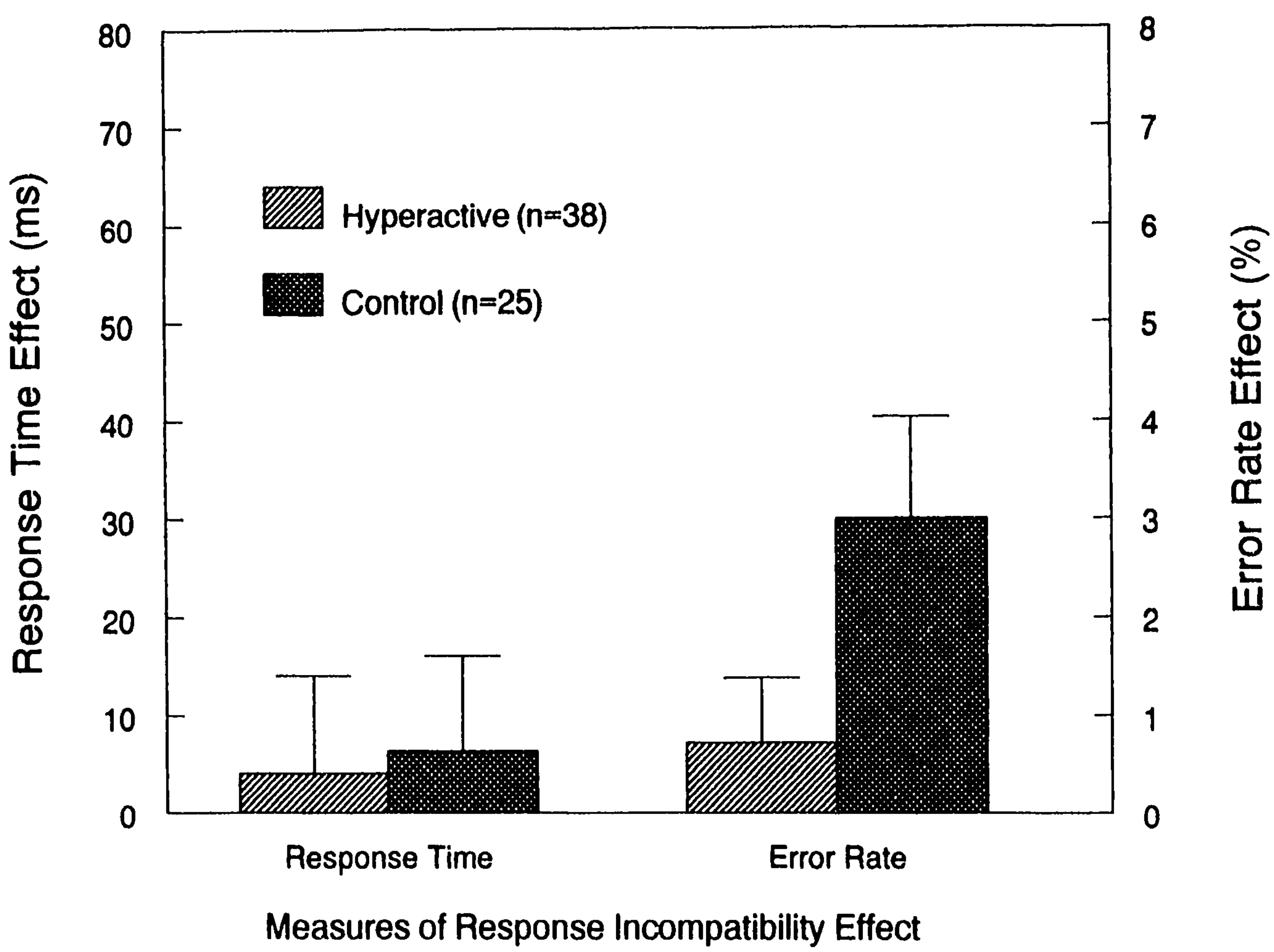

Figure 11. Mean (+SE) response incompatibility effects in the negative priming task for groups of hyperactive and control boys.

hyperactive/non-hyperactive differences in ignored repetition effects across the response time and error rate measures, effects from the two measures were combined in a χ^2 analysis identical to those performed on the ignored repetition data in Experiment 1. The numbers of subjects in each group who produced a 'negative' ignored repetition effect (i.e., negative priming) in neither, in one, or in both the response time and error rate measures are presented in Table 6. The resulting χ^2 was significant, $\chi^2(2, N = 63) = 7.27$, $p < .03$, suggesting that the between-group t-tests may have lacked the power to detect differences between the ignored repetition effects produced by the hyperactive and non-hyperactive boys in Experiment 2.

Calculations of the sample sizes needed to find statistically significant differences between the ignored repetition effects produced by the two groups given the effect sizes and standard deviations generated in Experiment 2 indicate that it would be necessary to have 49 and 101 subjects per group for the error rate and response time measures respectively (see Appendix B). The same calculations carried out on the ignored repetition data from the letter identity task in Experiment 1 produced similar minimum sample size estimates of 41 and 61 for the two measures. By combining the data from the letter identity tasks in the two experiments, sufficient power should be made available to reveal statistically significant differences in between-group t-tests of the error rate measure of the ignored repetition effects produced by the hyperactive and non-hyperactive children, and possibly in t-tests of the response time measure.

Combined Analysis of Letter Identity Tasks from Experiments 1 and 2

Although not identical to the letter identity task from Experiment 1, the negative priming task used in Experiment 2 utilized the same type of stimuli (letters), and employed a similar procedure. Response times and error percentages to the control trial prime and probe displays for Experiments 1 and 2, and for the two experiments combined, are shown in Figures 12a and 12b.

Table 6

Frequency Counts of Subjects Producing Different Numbers of 'Negative' Ignored Repetition Effects for Non-hyperactive and Hyperactive Groups in Experiment 2.

Subject	Number of Negative Ignored Repetition Effects per		
Diagnostic Group	2	1	0
Non-hyperactive	13	7	5
Hyperactive	8	22	8

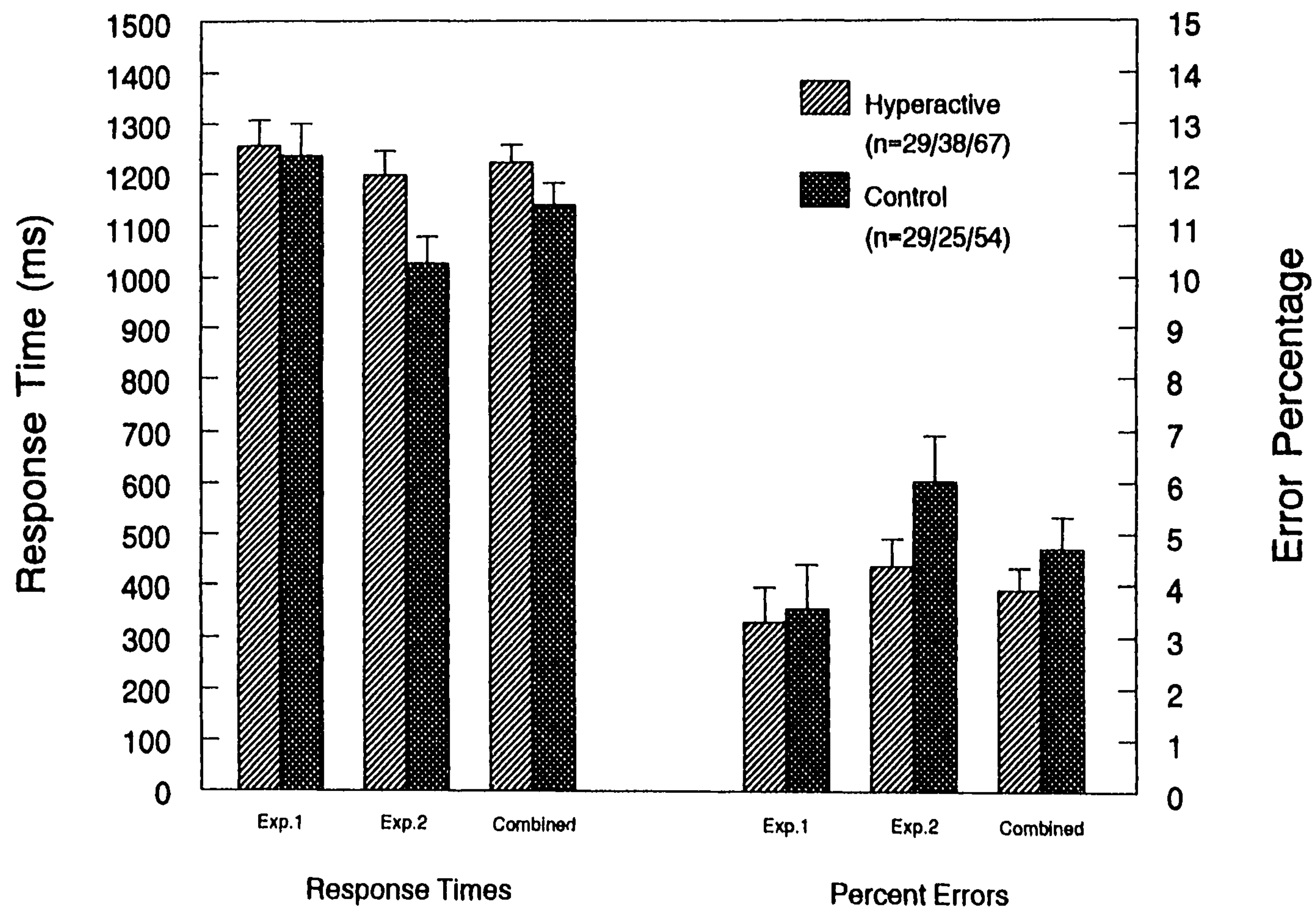

Figure 12a. Mean (+SE) response times and error percentages to control trial prime displays in the letter identity negative priming tasks for groups of hyperactive and control boys, from Experiment 1, Experiment 2, and Experiments 1 and 2 combined.

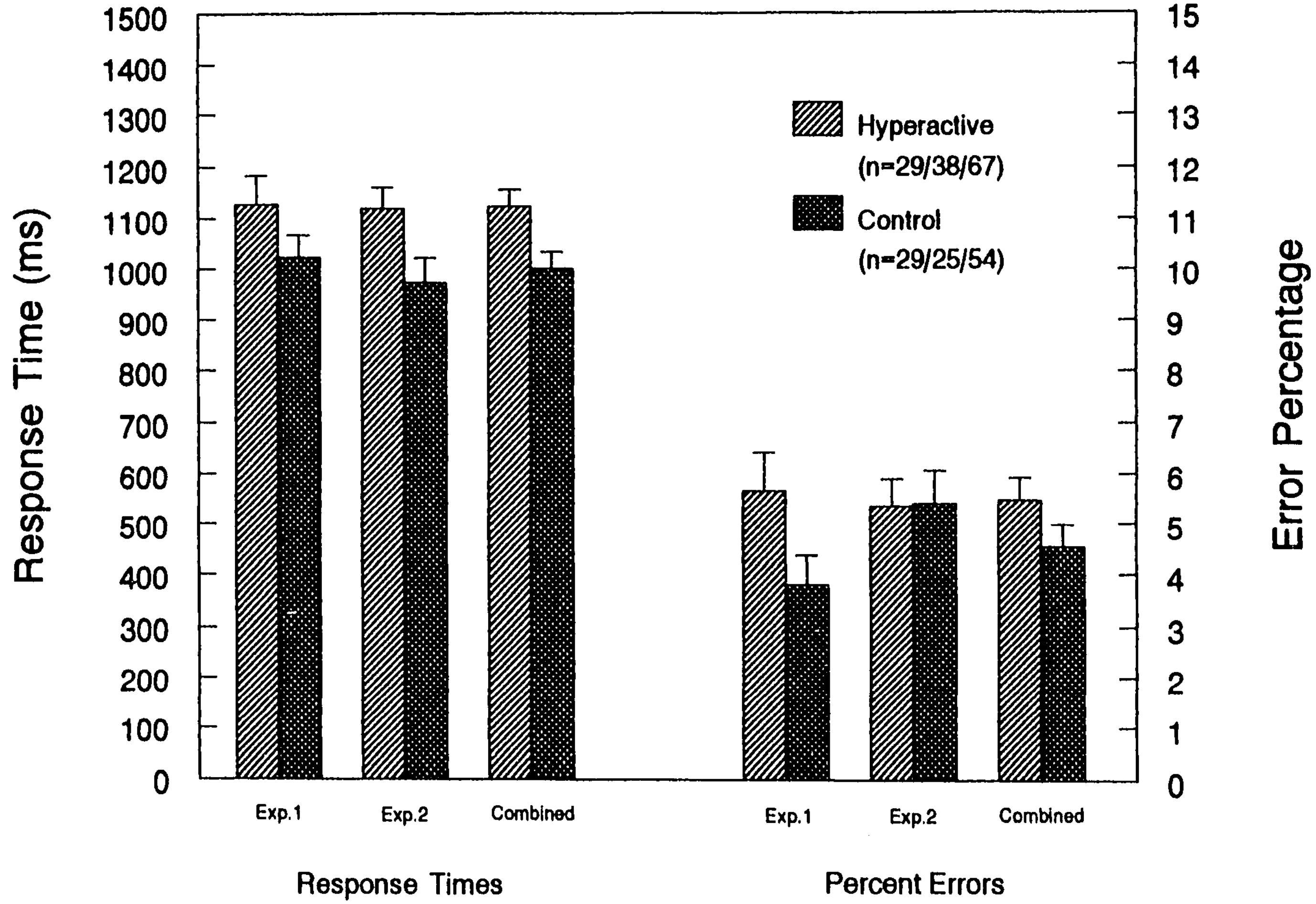

Figure 12b. Mean (+SE) response times and error percentages to control trial probe displays in the letter identity negative priming tasks for groups of hyperactive and control boys, from Experiment 1, Experiment 2, and Experiments 1 and 2 combined.

Analyses of the control trial responses indicated that performance of the hyperactive and non-hyperactive children was very similar across the two tasks. The response times and error percentages were submitted to 2 x 2 (Group by Task) ANOVAs, which revealed Task main effects in the prime responses, $F(1, 117) = 5.91$, $MSE = 88384.01$ and $F(1, 117) = 5.87$, $MSE = 15.66$ for response times and error percentages respectively, with subjects faster but less accurate in their responses to the primes in Experiment 2. No Task main effects were uncovered in the probe responses (both p values $> .30$). One Group main effect was significant, with the hyperactive boys responding more slowly than the non-hyperactive boys to the probe displays in the control trials, $F(1, 117) = 6.85$, $MSE = 67777.93$. Importantly, all Group by Task interactions were non-significant (all p values $> .13$), indicating that the two groups of subjects responded similarly to the two letter identity tasks.

The ignored repetition effects produced by the hyperactive and non-hyperactive children in the letter identity tasks in Experiments 1 and 2, and for the combined experiments, are shown in Figure 13. The ignored repetition effects produced by the non-hyperactive controls in the two tasks were submitted to one-tailed t-tests against zero, and both the response time and error rate measures were significant, $t(53) = 5.03$ and $t(53) = 2.55$, respectively. Two separate 2 x 2 (Group by Task) ANOVAs carried out on the response time and error rate data revealed one significant Task main effect, with subjects producing larger error rate ignored repetition effects in Experiment 2, $F(1, 117) = 6.82$, $MSE = 29.29$. Neither of the Group by Task interactions neared significance (both F values < 1.0).

The critical aspect of the analysis of the ignored repetition effects from the combined letter identity tasks was the evaluation of the Group main effects. As suggested from the sample size estimates calculated above, a statistically significant Group main effect for the error rate

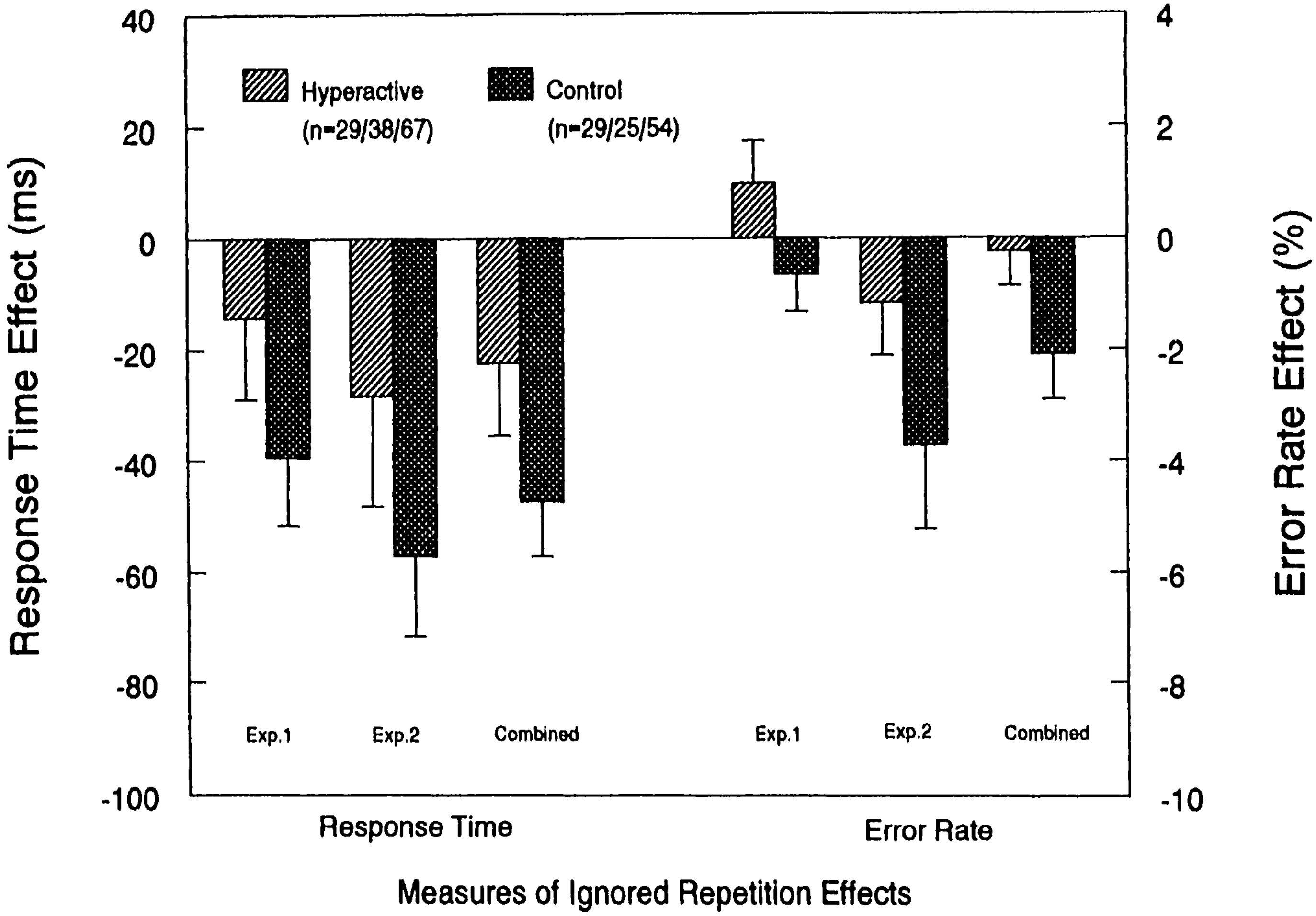

Figure 13. Mean (+SE) ignored repetition effects in the letter identity negative priming tasks for groups of hyperactive and control boys, from Experiment 1, Experiment 2, and Experiments 1 and 2 combined.

measure was found, $F(1, 117) = 4.37$, $MSE = 29.29$, and the Group main effect for the response time measure approached significance, $F(1, 117) = 2.51$, $MSE = 8497.35$, $p < .06$.[9]

By combining the samples from Experiments 1 and 2, sufficient power was gained to reveal a significant difference between ignored repetition effects produced by hyperactive and non-hyperactive boys in letter identity negative priming tasks. These results reinforce the assertion that hyperactivity is associated with abnormally small negative priming effects. Overall, in three tasks over two experiments in the current study, evidence was provided that hyperactive children produced ignored repetition effects that were significantly smaller than those produced by their non-hyperactive peers: in Experiment 1, across two tasks that required the same subjects to respond to different types of target stimuli; and across Experiments 1 and 2 with different samples of subjects performing two tasks that used similar target stimuli.

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[9]A between-group t-test of the WRAT-R Reading subtest data indicated significantly lower scores for the hyperactive subjects, but as in Experiment 1, the reading scores did not correlate significantly with either ignored repetition measure (both r values < .10) and were not considered further (Norman & Streiner, 1994).

General Discussion

It was hypothesized that in the present study hyperactive boys would produce significantly smaller negative priming effects than their non-hyperactive peers. Consistent with that hypothesis, statistically significant differences between age-matched hyperactive and non-hyperactive groups were revealed across spatial localization and letter identification negative priming tasks in Experiment 1. Although differences between mean negative priming effects for hyperactive and non-hyperactive children in a letter identification task in Experiment 2 again suggested that less negative priming was produced by the hyperactives, the between-group differences were not statistically significant. The outcome of power analyses of the letter identification tasks in Experiments 1 and 2 indicated that pooling the samples from the two experiments would provide sufficient power to reveal significant hyperactive/non-hyperactive differences. A combined analysis of the data from the two letter identification tasks verified the results of the power analyses by showing that the hyperactive boys produced significantly smaller negative priming effects than the non-hyperactive controls across the two experiments.

The significant difference in negative priming effects produced by hyperactive versus non-hyperactive boys in the present study is a novel and important finding. A previous study failed to find statistically significant *differences* between groups of hyperactive and control children, despite the fact that only control children produced statistically significant ignored repetition effects (McLaren, 1989). The present study uncovered the same evidence of significant ignored repetition effects for non-hyperactive subjects, but in between-group statistical analyses these effects also were found to be significantly larger than those produced by hyperactive children.

This finding of less negative priming with hyperactive children is important because it suggests that process models of the negative priming effect may be employed to identify the critical processes underlying the attention deficit that is characteristic of hyperactivity disorder. Previous studies of inattention and hyperactivity have relied on measures of the apparent distraction that is thought to be caused by irrelevant stimuli, with an underlying assumption that heightened distractibility is synonymous with impaired selective attention. While research of this type may indicate that hyperactive children are more easily distracted, and therefore less attentive, these studies make no inroads in the pursuit to understand the critical mechanisms underlying the hyperactive children's selective attention deficit. The successful application of the negative priming paradigm to the investigation of hyperactivity in the present study has provided an opportunity to assess potential process models of hyperactive inattention.

Although the negative priming paradigm proved to be effective in discriminating between samples of hyperactive and non-hyperactive children, differences between the ignored repetition effects produced by the two types of subjects were sufficiently small and variable that moderately large sample sizes were needed to achieve statistical significance. The apparent need for large samples, or for repeated testing of the same samples, is of particular concern for researchers of hyperactivity because of the great expense in time and financial resources required to conduct such studies. Before the negative priming paradigm can become a truly useful and informative tool in hyperactivity research, it is necessary to gain a better understanding of why differences between hyperactive and non-hyperactive children on this type of task are difficult to measure, and if anything can be done to improve the power of the task to distinguish hyperactive children from their peers.

Answers to questions regarding the lack of robustness of hyperactive/non-hyperactive differences in negative priming may lie in the heterogeneous nature of the hyperactive population, and in the theoretical interpretation of the negative priming effect itself. With regard to the non-homogeneity of hyperactive samples, it is possible that not all subgroups of hyperactive children produce abnormally small negative priming effects, and therefore that the size of differences between non-hyperactive and hyperactive groups will depend on the proportion of the hyperactive sample consisting of members of certain subgroups. Alternatively, differences in negative priming produced by hyperactive and non-hyperactive children may be hard to detect because ignored repetition effects in fact do not reflect attentional phenomena directly, and therefore the negative priming task is not ideal for the study of hyperactive inattention. Each of these approaches toward the further investigation of negative priming and hyperactivity will be explored in turn.

Subgroups of Hyperactive Children

One strategy for researchers who wish to maximize any potential differences between their hyperactive and control subjects would be to alter the selection criteria used to identify hyperactive children for studies. One method of doing this would be to widen the necessary breadth of the behavior problems that result in categorization as hyperactive, resulting in samples of hyperactive children with a more pervasive disorder. This approach is the route that has been taken recently with the DSM-IV (American Psychiatric Association, 1994). To be given a diagnosis of AD/HD, a child now must display symptomatic behavior in at least two different settings (e.g., home **and** school), although the number of necessary symptomatic behaviors in a given setting has been reduced. The sections below describe and discuss the impact within the present study of defining hyperactivity based on the observed breadth of the disorder.

Pervasive versus Situational Hyperactivity.

The current emphasis on multiple settings, or 'pervasiveness' of hyperactivity disorder, reflects the belief by many researchers that the more widely spread the problematic behavior, the more valid the purported case of the disorder (e.g., Barkley, 1990; Boudreault et al., 1988; Goodman & Stevenson, 1989; Schachar, Rutter, & Smith, 1981; Schleifer, Weiss, Cohen, Elman, Cvejic, & Kruger, 1975; Sergeant, 1988; Taylor, 1986; van der Meere & Sergeant, 1987, 1988a, 1988b; van der Meere et al., 1991). However, other researchers have cautioned against relying on pervasiveness of symptoms as a hallmark of 'true' hyperactivity, instead suggesting that attention should be paid to subgroups of hyperactive children whose behavior problems are limited to a single situation such as school or home, as well as to those whose behavior problems occur under a variety of circumstances (Costello, Loeber, & Stouthamer-Loeber, 1991; McArdle, O'Brien, & Kolvin, 1995; Searight, Nahlik, & Campbell, 1995). Indeed, it would be prudent not to exclude non-pervasive, or 'situational', hyperactive children given the results of the recent Ontario Child Health Study, which indicated that approximately 85% of hyperactive children have behavior problems that are situation-specific (Offord et al., 1989). Conversely, it would be disappointing to miss key pieces of evidence in the quest to understand hyperactivity because samples of hyperactive subjects in research studies were 'watered down' with situationally hyperactive children, thus masking true hyperactive/non-hyperactive differences.

The distinction between pervasive and situational subgroups of hyperactive children can be interpreted as being quantitative or qualitative in nature. Researchers who have adopted the quantitative position have argued that hyperactivity that is limited to a single context is a milder form of the more severe disorder that is observed in pervasively hyperactive children (e.g., Barkley, 1990; Goodman & Stevenson, 1989; Schachar & Logan, 1990b; Schachar et al., 1981; Sergeant, 1988).

Not only does the quantitative approach have the appeal of simplicity and parsimony (only one kind of 'hyperactivity' disorder, with a continuum of different degrees of severity), but it also has face validity (hyperactive symptoms that occur in more places create problems for more people, therefore widespread symptoms must represent a more severe disorder). Furthermore, the quantitative view is consistent with the results of comparisons across a number of psychosocial risk factor, diagnostic, and cognitive variables that have shown pervasive hyperactives to be more impaired than situational hyperactives, who in turn were impaired relative to control subjects (Boudrealt et al., 1988; Goodman & Stevenson, 1989; Schachar et al., 1981, 1995; Schleifer et al., 1975). Other studies that have restricted their focus to the performance of pervasive hyperactives on a variety of response inhibition tasks have found evidence of significant deficits, indicating that this subgroup of hyperactive children have difficulties with at least one form of inhibition (Barkley et al., 1992; Carter et al., 1995; Oosterlaan & Sergeant, 1996; Ross et al., 1994; Sandberg, Rutter, & Taylor, 1978; Shue & Douglas, 1992).

Alternatively, some researchers have argued against the quantitative interpretation of pervasive versus situational hyperactivity, opting instead for a more qualitative view towards different context-constrained subtypes (Costello et al., 1991; McArdle et al., 1995). Consistent with the notion that a given hyperactive behavior problem is not necessarily the same when it occurs in one context versus another, a factor analysis of behavioral symptoms reported by parents, teachers, and clinicians revealed that clusters formed according to the person reporting the symptoms, and not by symptom categories such as inattention or overactivity (Langhorne, Loney, Paternite, & Bechtoldt, 1976). More recent factor analyses of parent and teacher ratings of hyperactivity found that even though these two sources produced two similar pairs of factors, agreement between parents and teachers on specific behaviors was very poor (Bauermeister, Bird, Canino, Rubio-Stipec, Bravo, & Alegria, 1995). Other researchers also have reported little agreement between parent and teacher ratings of hyperactive behaviors (Rapoport & Benoit, 1975; Sandberg et al., 1978; Szatmari, Offord, Siegel, Finlayson, & Tuff, 1990; Webster-Stratton, 1988). Findings that inattention and overactivity are not the same when they are rated by different observers in different contexts suggests that the distinctions between pervasive and situational hyperactivity and between hyperactivity within distinct situations, are more qualitative than quantitative in nature.

Across the small number of studies that have examined pervasive and situational hyperactivity separately, the majority have not discriminated between children whose problem behavior is restricted to the home (Home-only) and children whose hyperactivity is only present at school (School-only). As a result, there are very few studies that have specifically contrasted Home-only and School-only subtypes of situational hyperactivity. Two previous studies that did include independent groups of pervasive (Home-&-School), Home-only, and School-only hyperactive children both resulted in conclusions that School-only hyperactive children had greater deficits than their Home-only counterparts, who in turn appeared to have little if any deficit when compared to non-hyperactive controls (Goodman & Stevenson, 1989; Schachar et al., 1995). In addition, in a recent study that examined the relationship between results from screening children for the risk of behavioral disorders and later diagnoses of hyperactive subtypes, McArdle et al. (1995) found that Home-&-School and School-only diagnoses, but not Home-only diagnoses, were related to screening outcomes. Other studies that have examined the relationship between ratings of hyperactive behaviors and the performance of hyperactive children on a variety of tasks have found stronger correlations between *teacher* ratings and children's task performance than between *parent* ratings and performance (Barkley, 1991; Chelune et al., 1986; Goodman & Stevenson, 1989). In their review of the DSM-IV diagnostic category of AD/HD, Searight et al. (1995) concluded that emphasis should be placed on teacher ratings, and that hyperactive symptoms that are identified only at home should be discounted as unreliable evidence of ADHD.

In the context of the quantitative interpretation of pervasive versus situational hyperactivity, the research findings outlined above support a prediction for the present study that the Home-&-School hyperactive boys should show the greatest, and perhaps the only, deficit in ignored repetition effects among the three hyperactive subgroups. In contrast, if context-defined hyperactive subtypes are qualitatively different from each other, and the classroom is the most reliable context for identifying hyperactivity, it would be expected that groups of Home-&-School and School-only hyperactive boys both would show deficits in negative priming, and that the group of Home-only hyperactive boys may display equivalent negative priming to that produced by controls.

The 67 hyperactive boys from the combined analysis of the letter identity tasks from Experiments 1 and 2 were divided into 3 subgroups based on the context(s) in which their hyperactivity had been identified. Boys who were categorized as hyperactive by both parents and teachers were called Home-&-School hyperactives, boys who displayed their hyperactive behaviors only at home were called Home-only hyperactives, and boys who were identified only by their teachers as hyperactive were called School-only hyperactives. Three of the hyperactive children from Experiment 1 had been 'borderline' in one context and thus could not be categorized clearly as pervasively or situationally hyperactive and were excluded. Of the remaining 64 hyperactive children, 21 were Home-&-School hyperactives, 18 were Home-only hyperactives, and 25 were School-only hyperactives.

Each hyperactive boy in each subgroup was paired with the closest age-matched non-hyperactive control subject from the same experiment.[10] The response time and error rate ignored repetition effects for each of the non-hyperactive/hyperactive subgroup pairings are

[10] This resulted in some non-hyperactive boys serving as control subjects for more than one subgroup of hyperactives.

shown in Figure 14.[11] The result of dividing the samples of hyperactive children from the present study into context-defined subgroups suggests that a deficit in negative priming was associated primarily with boys whose hyperactive behavior was manifested at school but not at home. Combined across the two experiments, the School-only hyperactive boys produced mean ignored repetition effects that were positive in direction for both the response time and error rate measures, providing no evidence of negative priming for this subgroup of hyperactive children.

The apparent restriction of the negative priming deficit to the School-only subgroup raises important questions about the Home-&-School subgroup, as the children in this latter group were categorized by their teachers as hyperactive in the same manner as their School-only counterparts. It may be that School-only hyperactives are children who have specific selective attention deficits, which are most likely to manifest themselves in an attention-demanding situation such as a classroom. Apparent hyperactive behaviors might then appear in response to frustration or inability to maintain focus on tasks, as suggested by Cromwell, Baumeister, and Hawkins (1963):

> ...the subject with a short attention span who shifts quickly from one goal-directed activity to another may appear to the observer to have a higher rate of activity than a subject fixated at one task but exerting the same amount of activity....the superactivity of the so-called "hyperactive brain-damaged child" may be partly, or even completely, illusory because of the short attention span and frequent shifts of goal direction of such subjects. (p. 634)

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[11]The response time and error rate ignored repetition effects for each context-defined subgroup of hyperactive/non-hyperactive pairs were submitted to 2 x 2 (Group by Task) mixed ANOVAs with Group treated as a within-subject factor. Due to the post-hoc nature of these analyses, critical α levels were reduced to $p < .017$ by applying a Bonferroni correction. None of the ANOVA results surpassed the adjusted α level, although the Group main effects of both the response time and error rate ignored repetition effects for the School-only subgroup approached significance (both p values $< .05$).

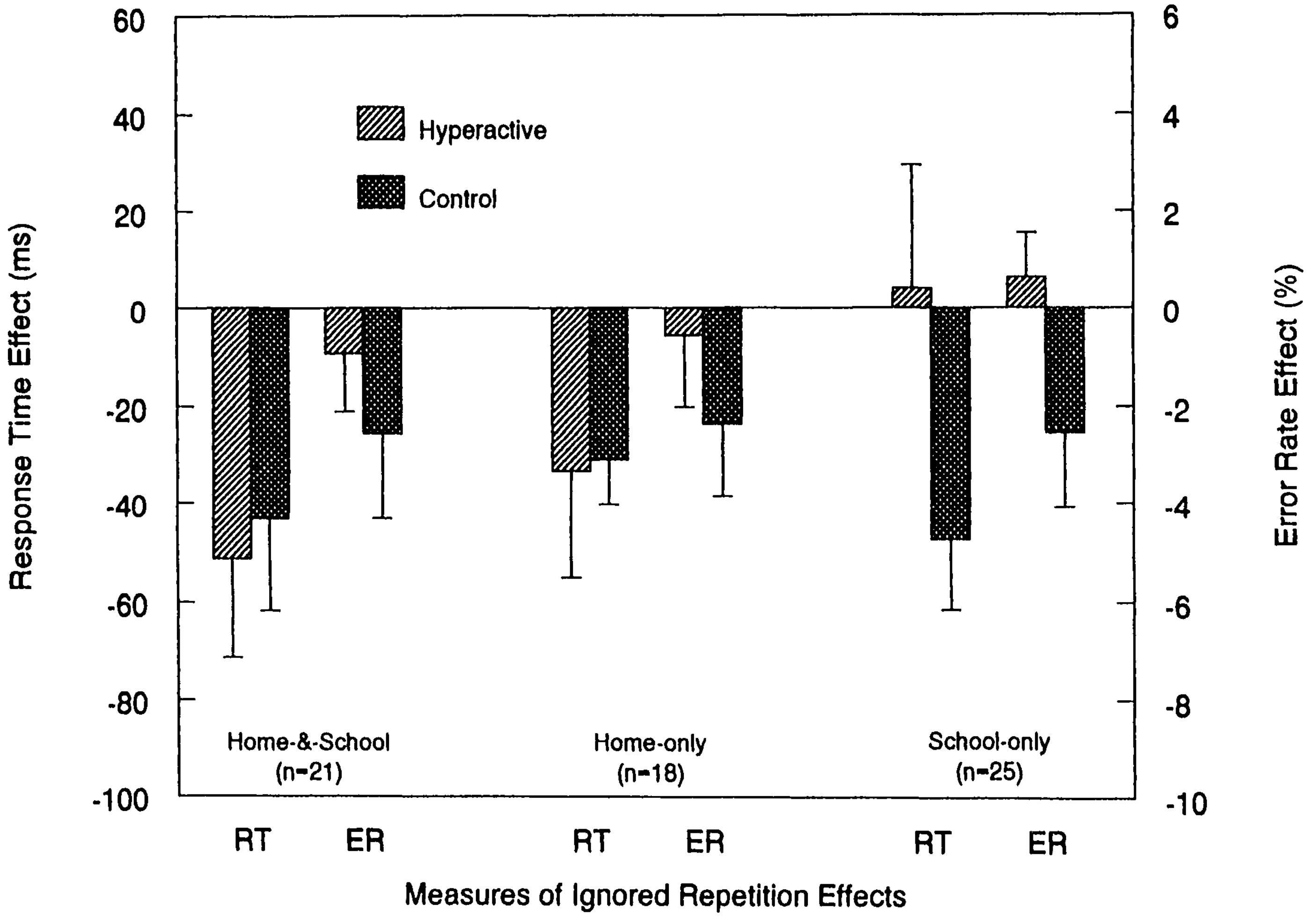

Figure 14. Mean (+SE) ignored repetition effects in the letter identity negative priming tasks from Experiments 1 and 2 combined, for context-defined subgroups of hyperactive boys and non-hyperactive controls. RT = response time; ER = error rate.

In contrast, there is evidence from other research that pervasively hyperactive children are truly physically overactive during all hours of the day and night (Porrino et al., 1983). The attention problems experienced by Home-&-School hyperactives therefore may be a result of being 'off-task' due to their overactivity (e.g., Campbell, Endman, & Bernfeld, 1977; Fischer et al., 1990; Schleifer et al., 1975), and thus may 'disappear' when physical activity levels are controlled, as is usually the case in an experimental setting.

Interpretation of Context-Defined Subtypes

School-only Hyperactive. A re-examination of the samples of subjects used in past visual selective attention studies involving hyperactive children supports the contention that true attention deficits may be limited to the School-only subtype. Studies that have failed to find evidence of impaired selective attention in hyperactive children have excluded School-only hyperactives, either intentionally or by virtue of their diagnostic procedures (Aman & Turbott, 1986; Fischer et al., 1990; van der Meere & Sergeant, 1988b). Conversely, studies that have reported significant visual selective attention deficits in hyperactive children have diagnosed hyperactivity based on behavior ratings from teachers, and thus included both School-only and Home-&-School hyperactives, while excluding Home-only hyperactives (Ceci & Tishman, 1984; Radosh & Gittelman, 1981; Rosenthal & Allen, 1980). Furthermore, the only previous study to examine negative priming in hyperactive children used only a teacher rating scale to categorize subjects and resulted in findings that, although inconclusive, were suggestive of a hyperactivity-related deficit (McLaren, 1989). A key factor in the success of these latter studies may be the fact that over 80 percent of boys who demonstrate their hyperactivity at school are School-only hyperactives (Offord et al., 1989). By relying on ratings from teachers, these previous researchers most likely obtained samples consisting of hyperactive children that were predominantly of the School-only subtype.

The negative priming effects produced by the context-defined subgroups in the present study suggest that there may be *qualitative* differences between situational and pervasive subtypes of hyperactivity disorder. As suggested above, it may be that the overactive and disruptive behaviors displayed by School-only hyperactives are somewhat epiphenomenal, resulting from an underlying selective attention problem, a causal mechanism of which may be the failure to inhibit cognitive processing of distracting stimuli. The primary nature of the attention deficit of these children would explain why their behavior problems are restricted to the classroom, an environment that makes great demands on attention. Furthermore, the formal structure of the classroom environment, accompanied by the watchful eye of a teacher, whose role in part is to ensure that children are attentive to their work, increases the likelihood that the inattention of a child will not go unnoticed. Hyperactive children who primarily suffer from a selective attention deficit rarely would be required to devote their impaired attention skills to tedious, mentally challenging tasks when at home or at play, and thus would not appear to parents to be especially inattentive or overactive. However, children with attention problems are almost certain to struggle with most of the task demands at school and are likely to be noticed there when their inattention gets the better of them, thus leading to diagnostic categorizations as School-only hyperactives.

<u>Home-&-School Hyperactive.</u> According to the *quantitative* interpretation of context-defined hyperactivity subtypes, the most profound diminishment in negative priming should have been found with the Home-&-School hyperactives. Clearly this subgroup of hyperactive children did not produce the greatest reduction in negative priming, despite the pervasiveness of their disorder.

There is some evidence in the literature that Home-&-School hyperactives do suffer from a type of disinhibition, but their problem appears to be in withholding physical responses when they are required to do so. Several studies have revealed Home-&-School hyperactive children to be less able to hold back their responses than non-hyperactive control children in Go/No-Go and other response control tasks (Oosterlaan & Sergeant, 1996; Ross et al., 1994; Schachar et al., 1995; Shue & Douglas, 1992; Trommer et al., 1988). If Home-&-School hyperactives have a primary deficit of physical overactivity, it may be that this problem is especially likely to manifest itself when these children are required suddenly to inhibit physically responding in the presence of a stimulus that has been associated previously with a need to produce a rapid response. Future studies should focus on the physical activity levels of Home-&-School hyperactives, and how their overactivity impedes their ability to complete tasks successfully, including the inhibition of physical responses when necessary.

Although the ignored repetition effects produced by the Home-&-School hyperactives in the present study suggest that there may not be a link between their inattentive behaviors and negative priming, a recent study examining evoked brain potentials produced results suggesting that pervasively hyperactive children may have a deficit in an alternative selective attention mechanism (Satterfield, Schell, & Nicholas, 1994). Satterfield and his colleagues measured evoked potentials related to attended and unattended auditory presentations, and found that Home-&-School hyperactives did not produce increased responses to the to-be-ignored stimuli as compared to control subjects, but they did produce weaker responses to the to-be-attended stimuli. The possibility that pervasive hyperactives do have a primary attention deficit that is a result of insufficient processing of targeted information needs to be explored in future research (but see the presentation below of *attended repetition* data from the present study).

Home-only Hyperactive. Based on the results of past and present research, it appears that future studies involving Home-only hyperactive children should be directed away from investigations of attention or response control deficits, and perhaps instead towards examinations of the home situation itself. Several studies have shown that parent ratings of the activity levels of their purportedly overactive children bear little relation to objective measures of the children's actual physical activity (Barkley, 1991; Barkley & Ullman, 1975; Campbell, Schleifer, Weiss, & Perlman, 1977; Rapoport & Benoit, 1975; Webster-Stratton, 1988). In their review, Searight et al. (1995) concluded that Home-only hyperactivity may be best understood as resulting from family conflict, parent's unrealistic standards for their children's behavior, or psychological problems with the parents themselves.

Models of ADHD and Qualitatively Different Subtypes. The identification of primarily inattentive and primarily overactive subtypes of hyperactivity is consistent both with observations of hyperactive children made a half century ago, and with a qualitative model of ADHD put forth more recently. Strauss and Lehtinen (1947) described two distinct types of hyperactive child: one type encompassed children who were constantly looking around and moving about, while the other type included children who did not move around very much, but who had difficulty attending to target stimuli within their own work. More recently, Hunt, Hoehn, Stephens, Riley, and Osten (1994) argued for the existence of three distinct subtypes of hyperactivity. Among these, their "Cognitive Deficits" subtype was marked by a basic deficiency in selective attention, along with hyperactive behavior that was more fidgety than grossly overactive. Hunt et al. stated that "[these ADHD children] primarily exhibit attentional disturbances and are highly distractible and poorly organized. Their primary deficit in stimulus filtering impairs selective attention....Symptoms may not be apparent until the child enters school and significant attentional focusing is required" (p. 108). Hunt and his colleagues proposed that, in contrast, an

"Overaroused" subgroup of hyperactive children were defined by their primary problem of extreme and uncontrolled overactivity and impulsivity. These children would first be identified by parents, when the children were around two to three years old, although their problems would continue throughout their school years.

The Cognitive Deficits subtype of hyperactivity characterized by Hunt et al. (1994) appears to correspond closely to the School-only subgroup in the present study. This inattentive, school-based route to a hyperactive categorization stands in contrast to the global overactivity of children of the Overaroused subtype, who would correspond most closely to the Home-&-School subgroup in the present study and to 'pervasive' hyperactives in general. The negative priming effects produced by the School-only and Home-&-School boys provide support for the distinction made between the primary etiologies of the Cognitive Deficits and Overaroused ADHD subtypes, and suggest that future research should be focussed on further examinations of the characteristics of the subtypes outlined by Hunt and his colleagues.

Models of Negative Priming

It appears that a potentially successful method of improving the utility of the negative priming paradigm as a tool for discriminating between hyperactive and non-hyperactive children may be to restrict samples of hyperactive subjects to include only children of the School-only situational subtype. The implication that reduced negative priming may be found only with particular subgroups of hyperactive children emphasizes the question of exactly what processes or mechanisms underlie the negative priming effect. It is possible that negative priming is not an index of selective attention processes, and that specific subgroups of hyperactive children who produce small negative priming effects are in fact suffering from a deficit in some other cognitive domain, perhaps not directly related to their hyperactivity. The determination of the best theoretical model of negative priming should help to clarify why differences between hyperactive and non-hyperactive children are difficult to find, and what direction should be taken in future research on, and treatment of, hyperactive children.

Distractor Inhibition

The distractor inhibition model interprets negative priming to be an attentional phenomenon. According to the distractor inhibition approach, negative priming occurs because some aspect of the mental representation of a 'probe' target item was inhibited as a part of the selective attention process when that target appeared as a distractor during a past processing episode (Neill, 1977; Tipper, 1985). Consideration of the hyperactive/non-hyperactive differences in negative priming in the context of the distractor inhibition model leads to the conclusion that hyperactive children do not inhibit irrelevant visual stimuli to the same degree that non-hyperactive children do, resulting in a selective attention deficit for hyperactive children.

Clearly, the utility of negative priming as a tool in the study of hyperactivity would be compromised if negative priming was found not to be an attentional phenomenon. Although the inhibition hypothesis has been a widely adopted attentional interpretation of negative priming, it has been challenged over the past two decades by a number of research findings. One cluster of research results that appears to be incongruous with the distractor inhibition model concerns the prediction that negative priming ought to be directly related to distractor interference. Some studies have shown negative priming and interference to be directly related (e.g., Beech, Baylis, et al., 1989; Tipper & Baylis, 1987; Tipper et al., 1988), but other investigations have indicated no consistent relationship exists between these two dependent variables (Beech, Agar, & Baylis, 1989; Beech & Claridge, 1987; Driver & Tipper, 1989; Fox, 1994b, 1995b; Tipper, Weaver, Kirkpatrick, & Lewis, 1991; Visser et al., 1996).

In addition to the lack of a stable relationship between negative priming and interference, a number of other research findings that are difficult to integrate with the distractor inhibition model have surfaced. Although inhibition of prime distractors is theoretically independent of the selection demands during processing of the probe, there are now several studies that have shown that when there is little or no selection required in the probe display (i.e., the distractor is either degraded or absent) negative priming disappears or even becomes facilitatory (Kane, May, Hasher, Rahhal, & Stoltzfus, 1997; Lowe, 1979; Milliken & Joordens, 1996; Milliken, Joordens, Merikle, & Seiffert, in press; Moore, 1994; Tipper & Cranston, 1985). Other problematic findings for the distractor inhibition model include results indicating that negative priming may be dependent on the inclusion or exclusion of a threshold proportion of target-to-target trials in a task (Allport et al., 1985; Kane et al., 1997; Lowe, 1979; May, Kane, & Hasher, 1995; Neumann & Deschepper, 1991; Tipper & Driver, 1988), and that the interval between the response to the prime display and the onset of the probe display affects negative priming, but only if manipulated within subjects rather than between subjects (Hasher et al., 1991; Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992; Stoltzfus et al., 1993; Tipper, Weaver, Cameron, Brehaut, & Bastedo, 1991: but see Hasher, Zacks, Stoltzfus, Kane, & Connelly, 1996).

At an early stage in the development of the inhibition hypothesis, Tipper and Cranston (1985) acknowledged that the notion of simple suppression of the activation state of a distractor's mental representation could not account for negative priming effects under all circumstances. They suggested that the cost measured in the response to a probe display in an ignored repetition trial was the result of inhibition of the *response* associated with the prime distractor rather than inhibition of the distractor's perceptual representation per se. More recently, Houghton and Tipper (1994) have revised the inhibition model by incorporating the concept of opposing excitatory and inhibitory processes simultaneously acting upon the distractor in the prime display.

According to the Houghton and Tipper model, when the prime distractor disappears the excitatory component ceases resulting in an imbalance toward the inhibitory component. Negative priming on an ignored repetition trial remains a result of residual inhibition impeding the response to the probe target. Within the context of the present study of attention and hyperactivity, the key feature of all instantiations of the distractor inhibition hypothesis is that an absence of negative priming implies a failure to inhibit some aspect of the mental representation of a prime distractor.

The growing number of negative priming results that are inconsistent with some or all forms of the distractor inhibition model have given rise to a group of alternative models that invoke the role of memory for previous displays as the principle mechanism underlying negative priming (e.g., Keele & Neill, 1978; Lowe, 1979, 1985; Park & Kanwisher 1994; cf. Kahneman, Treisman, & Gibbs, 1992). Although the inhibition hypothesis has been defended by Tipper and his colleagues (Allport et al., 1985; Houghton & Tipper, 1994; Milliken, Tipper, & Weaver, 1994; Tipper & Cranston, 1985; Tipper et al., 1994; Tipper, Weaver, Cameron, Brehaut, & Bastedo, 1991; Tipper, Weaver, & Milliken, 1995), a memory-based hypothesis put forth by Neill and his colleagues (Neill & Valdes, 1992; Neill et al., 1992) has emerged as a strong contender to the attention-based distractor inhibition model (for reviews see Fox, 1995a, and May et al., 1995).

Episodic Retrieval

Neill et al.'s (1992) 'episodic retrieval' model of negative priming is based on Logan's (1988) instance theory of automatization. Logan suggested that response to a target stimulus is determined either by controlled processing of the stimulus display, or by automatic retrieval of prior processing episodes. These two processing routines are presumed to race against one another, with the successful processing operation dictating the nature of the task response. According to the episodic retrieval account of negative priming, when subjects process the probe display, traces of the elements of the prime stimulus are automatically retrieved, including tags indicating the response (or lack thereof) that was associated with each of the prime elements. By this theory, response impairment occurs on ignored repetition trials because automatic retrieval results in conflict between past and present responses or response tags associated with the probe target.

In a recent study, Neill (in press) has presented strong evidence indicating that episodic retrieval plays a key role in negative priming. Neill demonstrated that negative priming was contingent on a match between processing conditions present at the time of the probe and those present at the time of the prime, suggesting that negative priming depends on the contextual similarity of the prime and probe episodes. Contextual similarity, in turn, is presumed to facilitate automatic retrieval during processing of the probe display.

Within the framework of the episodic retrieval model, the results of the hyperactive/non-hyperactive comparisons in the present study could have two interpretations: 1) that hyperactive boys were not automatically retrieving traces of the prime displays, and therefore controlled processing of the probe displays was winning the race between processing routines; or 2) that hyperactive boys *were* automatically retrieving traces of the prime displays, but that the hyperactives were not tagging the prime display distractors with response information in the same manner as the non-hyperactive controls. These two possible interpretations will be considered in turn.

If controlled processing of probe displays is winning the race against automatic retrieval of prime display memory traces, then one might expect that prime display influences on probe display responses should never be present. With regard to this hypothesis, Neill (in press) has recently suggested that the positive priming that is typically found when prime targets repeat as probe targets also is a result of automatic retrieval. By equating the mechanisms underlying negative and positive priming, the prediction can be made that subjects who fail to produce negative priming also should fail to show positive priming when prime targets reappear as probe targets. An assessment of this prediction of the episodic retrieval hypothesis with regard to the findings from the present study can be made from the data collected in Experiment 2. On a small number of the filler trials, the target in the prime display repeated as the target in the probe display (called 'attended repetition' trials by Tipper, 1985). When performance on trials of this type is compared with performance on control trials, attended repetition trials usually result in facilitation in response times or error rates (e.g., Kane et al., 1997; Neumann & DeSchepper, 1991; Tipper, 1985; Tipper & Driver, 1988). According to the episodic retrieval hypothesis, given the lack of ignored repetition effects produced by the School-only hyperactives, this subgroup of boys also would be predicted to produce small or nonexistent facilitation on attended repetition trials. The attended repetition effects produced by each of the hyperactive subgroups and their control groups were calculated, and are shown in Figure 15. As can be seen, there is no evidence that any of the hyperactive subgroups failed to produce attended repetition effects.

If episodic retrieval underlies the ignored repetition effects in Experiment 2, indicating that School-only hyperactives failed to automatically retrieve representations of the prime displays, one would have difficulty explaining the abundant positive priming found for the School-only hyperactives on the attended repetition trials.[12] However, the episodic retrieval model might account for these results with the second of the two hypotheses outlined above. In particular, positive priming on attended repetition trials but no negative priming on ignored

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[12]Kane et al. (1997) suggested that performance on target-to-distractor (TD) trials should serve as a marker of the source of the negative priming effects, with cost on TD trials indicating episodic retrieval, and facilitation on TD trials indicating distractor inhibition. Experiment 2 of the present study included 'filler' trials of the TD type, but an examination of performance on these trials relative to control trials yielded no consistent patterns of facilitation or cost for either hyperactive or control subjects in any of the three hyperactive subgroups.

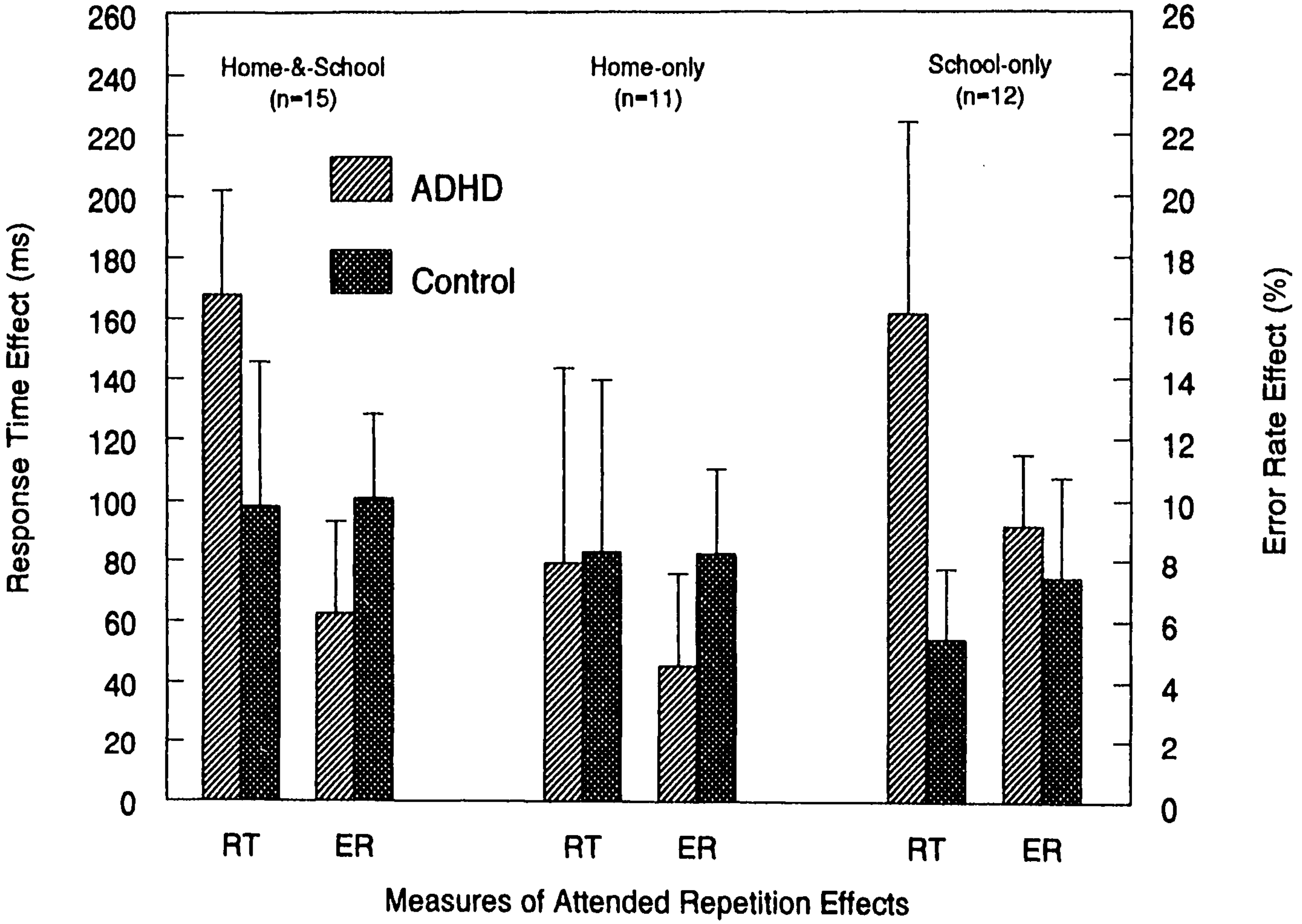

Figure 15. Mean (+SE) attended repetition effects in the letter identity negative priming task from Experiment 2 for context-defined subgroups of ADHD boys and non-hyperactive controls. RT = response time; ER = error rate.

repetition trials may have resulted for hyperactives if one assumes that prime distractors were processed differently by hyperactives and non-hyperactive controls. It may have been the case that the hyperactive boys failed to tag the distractors as 'ignored' during their processing of the prime displays, even though they had tagged the targets appropriately. However, to the extent that a memory-based model describes reduced negative priming as resulting from a failure to tag prime distractors as 'ignored', such a model becomes difficult to distinguish from an attention-based model that focuses on the 'tagging' process itself. In other words, the dependence of negative priming on aspects of the retrieval environment (see also Kane et al., 1997; Lowe, 1979; Milliken & Joordens, 1996; Moore, 1994; Tipper & Cranston, 1985; regarding the role of distractors in the probe display) does not negate the importance of attentional processing during the selection of a prime target. If it is assumed that what is reinstated during the probe task is the inhibitory processing carried out on the prime distractor, then the distractor inhibition and episodic retrieval accounts are not incompatible with one another. Importantly, this analysis implies that negative priming does not cease to be an attentional phenomenon just because it is also a memory retrieval phenomenon.

Neither the distractor inhibition model of Tipper and his colleagues (Houghton & Tipper, 1994; Tipper, 1985; Tipper & Cranston, 1985), nor the memory-based episodic retrieval model developed by Neill and his colleagues (Neill & Valdes, 1992; Neill et al., 1992) seems to afford a comprehensive account of negative priming. Some authors have attempted to combine the two approaches into a joint inhibition/memory-retrieval model, in which the process underlying negative priming effects can be either mechanism depending on specific parameters of the negative priming task itself (Fox, 1995a; Kane et al., 1997; May et al., 1995). A disadvantage to this dual process approach rests in its non-parsimonious nature. It encourages the addition of yet other purported mechanisms of negative priming if they are deemed necessary to explain any subsequent empirical findings that cannot be accounted for by either the distractor inhibition or episodic retrieval models.

One such empirical finding has been reported recently by Milliken and his colleagues (Milliken & Joordens, 1996; Milliken et al., in press). In several experiments they demonstrated that negative priming could be produced in the **absence** of a selection task in the prime display. Both the distractor inhibition and episodic retrieval models are based on the premise that ignored repetition effects arise via cognitive processing of the *prime* distractor. There is no simple manner in which either of these models could account for the presence of negative priming when there is no distractor to be inhibited in the prime display. In response to his findings, and to the increasing number of other inconsistencies between empirical data and either the distractor inhibition or episodic retrieval theories, Milliken has suggested reconsideration of the premise that negative priming effects are a direct result of processes carried out on the prime display. Instead, he has proposed an alternative model of negative priming that invokes the notion of selective attention to events in one time period in the presence of memory for events that occurred in a previous time period.

Temporal Discrimination

A key difference between the distractor inhibition and episodic retrieval models, and the temporal discrimination interpretation of negative priming, lies in the specification of what stimulus is being selectively attended to and what stimulus is being ignored. In both the distractor inhibition and episodic retrieval models, negative priming is hypothesized to be a byproduct of the act of selectively attending to the ***prime*** target while ignoring a ***concurrently presented*** distractor. Described in this manner, selective attention refers to a process occurring at a specific point in time that allows one to focus on relevant information in the physical presence of irrelevant information. The resultant negative priming measured on an ignored repetition trial is in effect the ghost of a process carried out during the prime display, illuminated against a background that is the response to the probe display.

In contrast to the distractor inhibition and episodic retrieval models, the temporal discrimination approach offered by Milliken (Milliken & Joordens, 1996; Milliken et al., in press) interprets negative priming as a measure of the ability to regulate influences of past processing on current processing. According to the temporal discrimination model, memory for the prime display is automatically retrieved during the processing of the probe display. It is hypothesized that at that time, the influence of memory for the just-completed processing of the prime display is blocked in an effort to ensure that the response to the probe target is based on the current processing of the probe display. Characterized in this manner, the negative priming paradigm is a measure of 'selective attention' defined as cognitive differentiation between events that occur at different points in time.

Within the framework of the temporal discrimination model, ignored repetition effects arise when one has difficulty differentiating between current and past sources of influence on one's processing of probe displays. On control trials, the lack of any correspondence between the constituent elements of the prime and probe displays makes it relatively easy to discriminate between information gained from processing the probe display and information remembered from the processing of the prime display. However, due to the partial overlap in the contents of the two displays on ignored repetition trials, cognitive separation of probe display processing from the memory of the processing carried out on the prime display is more difficult, and therefore probe responses on ignored repetition trials are impaired relative to probe responses on control trials.

The temporal discrimination model accounts for the facilitation to a probe response on an attended repetition trial by focussing again on the quality of the overlap between the prime and probe displays. Unlike ignored repetition trials, in which the partial overlap hinders discrimination between sources of influence on probe processing, the fact that the probe processing on an attended repetition trial is so much like the processing of the previous prime display allows one to abandon efforts to separate the sources of influence, and to simply repeat the response that was made for the prime display. The outcome is a probe display response that is faster and more accurate than the response to a probe on a control trial.

Temporal Discrimination and Hyperactivity. The results from the present study may indicate that hyperactive children are less able to protect their processing of the present against influences arising from their memories of the past. Although we make copious use of our past experiences to aid us with whatever task is at hand, we also need to be able to isolate our processing of current tasks from distracting influences of memories for past events. It may be that hyperactive children do not regulate potential influences from memories for the past, instead letting memory for the past wash over their current cognitive processing. If it is the case that hyperactives leave themselves open to influences of memory for prime processing on probe responses in a negative priming paradigm, while non-hyperactive controls are able to guard against potentially misleading sources of influence on probe responses, then between-group findings in negative priming tasks might be expected.

Findings of response impairment on ignored repetition trials for the control subjects in both Experiments 1 and 2 could be interpreted as evidence that these non-hyperactive boys were selectively attending to the probe targets by gating out possibly misleading information arising from their memories for the prime displays. Because the process of gating out memory influences would have operated more effectively for probe displays that were completely different from prime displays, the non-hyperactive boys would have taken less time to respond to probe targets on control trials than on ignored repetition trials. In contrast, the reduced negative priming produced by the hyperactive boys relative to the non-hyperactive controls would be consistent with an approach to probe processing that did not involve careful selective attention to the probe displays. If the hyperactive boys simply processed a probe target against the background of their memory for their processing of the prime display without gating out automatic memory influences, then reduced response impairment on ignored repetition trials relative to control trials would be expected. In fact, it is possible that some hyperactives might actually benefit on ignored repetition trials from the recent processing of the probe target as prime distractor, as a form of positive priming (cf. Marcel, 1983).

It is important to note that according to the temporal discrimination model, the results of the present study would not be taken to suggest that the hyperactive boys were outperforming their non-hyperactive counterparts on the ignored repetition trials. Instead, a reduced impairment on ignored repetition trials relative to control trials for hyperactive children would be a result of their impaired processing of probe displays on control trials ***as well as*** on ignored repetition trials. Evidence consistent with this postulation was found in the responses to the control trial prime and probe displays. An important advantage of gating out the influence of memory for past experiences is that it frees one to process a current task outside of interference from similar but not identical processes carried out in the past. By orienting to the 'newness' of control trial probe targets, non-hyperactive boys would have allowed themselves to reduce interference from their memories for the recently processed prime displays. They could then process and respond to the control trial probe targets as unique stimuli relative to the prime displays. In contrast, if the hyperactive boys were not regulating the influence of their memories for the prime displays while they were processing the probe targets, it would be expected that some interference would result, and that their responses would be impaired relative to their non-hyperactive counterparts. Such findings of impaired probe responses for the hyperactive boys on control trials were revealed in the analysis of Experiment 2, and in the analysis of Experiments 1 and 2 combined.

It does not appear that the hyperactive children had poorer responses to the control trial probe displays because they had a longer refractory period between successive responses than the non-hyperactive children. Evidence against this explanation of hyperactive/non-hyperactive differences was found in the savings in response times shown by the hyperactive children on attended repetition trials that were at least as great as the savings produced by the non-hyperactives (see Figure 15). Furthermore, in a study investigating single-task vs dual-task paradigms, Schachar and Logan (1990a) found that increasing the amount of time between two required responses did not reduce the second task response impairment shown by hyperactives relative to control subjects. This latter finding indicates that the second-response impairment experienced by hyperactive children is dependent on the ***occurrence*** of a preceding event, not on the duration of the interval between two events.

It also is not the case that the hyperactive children simply were poorer responders in general to the computer task displays than the non-hyperactive children. In Experiment 1 the hyperactive boys were as fast and accurate in their responses to the prime displays as were the control subjects, and in Experiment 2 although the non-hyperactive boys were faster to respond to the prime displays, it appeared to be at the expense of a higher error rate. Finally, the combined analysis of the letter identification tasks revealed no hyperactive/non-hyperactive differences in prime responses.

While the pattern of hyperactive/non-hyperactive responses across the control trial displays is consistent with the temporal discrimination approach, the lack of poorer hyperactive responding to the prime displays is somewhat problematic for the distractor inhibition model. If hyperactive/non-hyperactive differences in negative priming effects are a result of an impairment in how hyperactive boys selectively attend to targets in prime displays, it would seem unlikely that the hyperactives nonetheless would manage to respond with the same overall efficiency as non-hyperactives to those same prime displays. If the hyperactive boys in the present study did suffer from a selective attention deficit that limited their ability to discriminate prime display targets from the concurrently presented distractors, then some as yet unspecified compensatory process must have been at work to offset the impairment.

Overall, performance on the control trials by the hyperactive and non-hyperactive boys in the current study appears to be most compatible with the temporal discrimination model. The hyperactive children were impaired in their responses to probe control trials relative to their non-hyperactive peers, but were just as proficient as the non-hyperactives in responding to prime displays. This finding of an impairment only in second-task responses, relative to control subjects, indicates that during processing of the probe displays the hyperactives were suffering abnormally interfering effects from their processing of the primes, potentially due to a failure to gate out conflicting memory influences.

By addressing the separation of events in time as an attentional process, the temporal discrimination model provides an interesting alternative viewpoint of the negative priming effects produced by hyperactive and non-hyperactive children. A key role of attention in many circumstances, including the processing of probe displays in a negative priming paradigm, may be to bind processing of events to a particular time and place, and thus to regulate automatic memory retrieval. According to the temporal discrimination model, both automatic memory retrieval and the selective attention processes that gate out the influence of memories for prior events play critical roles in the generation of ignored repetition effects in a negative priming task. The hypothesized interaction of selective attention and memorial processes, across the contrasting demands of control and ignored repetition trials, defines the temporal discrimination approach as an intriguing, albeit not process pure, account of negative priming.

Finally, it is important to note that if the temporal discrimination model does eventually emerge as the preferred explanation of negative priming differences between hyperactive and non-hyperactive children, there still will be a question of what processes underlie the ability of hyperactive and non-hyperactive children to selectively attend to a target in the context of concurrently presented irrelevant stimuli. It appears from the error rates and response times to the computer task prime displays that the hyperactive and non-hyperactive boys were equally good at separating concurrent targets and distractors in relatively simple visual displays. In more complex displays such as those presented in the cartoon search task, however, the hyperactive boys performed significantly worse than their non-hyperactive peers, suggesting that they may have been less able to ignore the numerous appealing distractions in the cartoon pictures than the two or three extraneous letters in the computer task displays.

Summary

The present study has shown that hyperactive boys have a significant negative priming deficit when compared to non-hyperactive control subjects. The successful application of the negative priming paradigm to the study of hyperactivity is an important advance in that it allows for the interpretation of hyperactivity-related deficits within the context of specific process models of cognitive functioning. The evidence provided in the current study, indicating that negative priming is reduced in hyperactives, reinforces the belief that hyperactivity disorder has an associated selective attention deficit. Previous studies that had relied on distractibility measures of selective attention had produced equivocal results, which in turn had given rise to doubt that inattention was a key factor in hyperactivity. The present results contradict reservations regarding the importance of the role of attention in hyperactivity. By utilizing a dependent measure with a theoretical basis in underlying mechanisms of selective attention, the present study was successful in revealing processing deficits that might otherwise have been overlooked had more typical measures of inattention been used.

Although the present study was the first demonstration of a significant reduction in negative priming in hyperactive versus non-hyperactive children, it was noted above that there are a growing number of studies that have associated abnormally small negative priming with populations suffering from a variety of psychiatric problems or cognitive disabilities. The fact that subjects with schizophrenia, anxiety, obsessive-compulsiveness, impulsivity, mental retardation, and hyperactivity all have exhibited similar reductions in negative priming suggests the possibility that a common cognitive impairment may underlie this assortment of disorders. Although it seems likely that these different special populations are not all directly related disorders, it may be the case that they share an attentional deficit to which the negative priming paradigm is sensitive. An attentional deficit would be only one component of each disorder however, with a variety of other contributing cognitive impairments defining the final overall behavioral manifestation and subsequent clinical classification. Alternatively, it may be that negative priming is a measure that is sensitive to the functioning of a number of underlying cognitive processes in addition to attention, and thus reductions in negative priming may be brought about by any one of several deficient cognitive mechanisms, each of which in turn may be associated with a different behavioral or psychiatric disorder. Hopefully future research will clarify the nature of the relationship between negative priming and various special populations.

The fact that hyperactive/non-hyperactive differences in negative priming in the present study were somewhat small and variable suggested a need for a closer inspection of the heterogeneous nature of hyperactivity disorder itself. Post hoc examinations of some specific hyperactive subgroups indicated that reductions in negative priming may not be uniform across all hyperactive subtypes. The possibility that some subgroups of hyperactive children may have a more profound selective attention deficit than others also may cast light on the inconsistent findings reported from previous studies, some of which excluded particular hyperactive subtypes or failed to discriminate between pervasive and situational hyperactives. A visual inspection of the mean negative priming effects for the hyperactive subgroups in the present study appeared to show inconsistencies with the quantitative interpretation that situational and pervasive hyperactivity differ only in severity, instead indicating that hyperactive subtypes may be qualitatively distinct with possibly unique underlying etiologies.

The specific theoretical interpretation of the reduced negative priming shown by the hyperactive boys in the current study also was re-examined. The original theory espoused by Tipper (1985) and Neill (1977; Neill & Westberry, 1987) that small negative priming effects represented poor distractor inhibition has been challenged in recent years. An alternative theory that negative priming is a measure of memory processes (Neill & Valdes, 1992; Neill et al., 1992) rather than selective attention has gained some favor in the literature, but did not appear to be consistent with the findings from the present study. In contrast, a new model of negative priming presented by Milliken (Milliken & Joordens, 1996; Milliken et al., in press) that suggests negative priming effects are a measure of selective attention to events across the dimension of time appeared to account for the findings from the current study better than either of the other two approaches.

Future refinements of any theoretical models of negative priming will have to accommodate findings from research with special populations such as hyperactive children, and conversely, attempts to interpret results from future negative priming studies of hyperactivity should be made with consideration of each of the potential theoretical models.

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Appendix A

There were seven possible relationships between the letters in the prime and probe displays in the computer task in Experiment 2. These relationships, and their frequency of occurrence in the task, are outlined in the table below.

Relationship of letters between prime & probe displays	Example Displays (prime)	(probe)	Frequency (total = 261)	Percentage of Total Trials
no overlap (control trial)	WNW	HMH	117	44.83
distractor becomes target (ignored repetition trial)	MNM	HMH	27	10.34
target becomes distractor (filler trial)	WHW	HMH	28	10.73
distractor repeats (filler trial)	HWH	HMH	27	10.34
target repeats (filler trial)	NMN	HMH	27	10.34
target and distractor switch (filler trial)	MHM	HMH	21	8.05
target and distractor repeat (filler trial)	HMH	HMH	14	5.36

Appendix B

The formula used to calculate the sample sizes, from Norman and Streiner (1994, p. 61), was:

$$n = 2\left[\frac{(z_\alpha + z_\beta)\,\sigma_{avg}}{\Delta}\right]^2$$

with α set at .05 (1-tailed); β set at .40; Δ = the difference between the effects for the two groups; and σ_{avg} = the average of the standard deviations for the two effects, from the formula:

$$\sigma_{avg} = \sqrt{\frac{(n_{hyp} - 1)\,\sigma_{hyp}^2 + (n_{ctrl} - 1)\,\sigma_{ctrl}^2}{n_{hyp} + n_{ctrl} - 2}}$$

(G. R. Norman, personal communication, February 13, 1997).