INHIBITION IN VISUAL SELECTIVE ATTENTION:
EVIDENCE FROM NORMAL DEVELOPMENT AND AUTISM

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Abstract

Five- and 7-year-old typically developing children, and 12-year-old males with autism, were required to regulate their attention toward one location during a visual Go-NoGo task. The main Reversal condition (see Ozonoff et al., 1994) reversed the roles of the target and distractor stimuli during the test phase. Since this condition may confound two abilities that possibly exist as independent components of inhibition (the inhibition of a prepotent response, and disinhibition, or the ability to overcome built-up inhibition), additional conditions were designed to separately measure these abilities. Developmental findings suggest that although the ability to selectively attend to one location remains constant between 5 and 7 years of age, inhibition appears to develop during this time. The children with autism were able to perform as well as controls during the visual selective attention task (see also Ciesielski et al., 1990) and no evidence was found for enhanced or atypical inhibition in autism. Past evidence of perseveration in autism (Bryson, 1995) was not replicated in the present study. Correlational evidence, coupled with exploratory post-hoc analyses, suggests the possibility that prepotent inhibition and disinhibition may exist as separate components of inhibition, an intriguing finding that needs to be explored further.

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This work is dedicated in the memory of two very special souls: my beautiful friend, Michelle, and my beautiful grandmother, Lila.

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Introduction

Selective attention has a central role throughout the lifespans of both humans and other animals. Survival in a perceptually demanding environment depends on one's ability to direct attention toward relevant features in one's surroundings. Selective attention is a fundamental capability that can be achieved in visual, auditory, and somatosensory modes. Attention to relevant information allows us to fulfill our daily goals, behave appropriately in different situations, and communicate effectively with others. In essence, the ability to selectively attend to the environment provides us with intentional, controlled behavior.

The present study explored inhibitory processes involved in visual selective attention, notably, how inhibition develops in normal children and whether children with autism possess unique inhibitory control. An overview of the characteristics of autism will be presented first, followed by a summary of the literature on attention in autism. We will then turn to a discussion of attention and inhibition in normally developing children and adults. The normal development of inhibition will be considered relative to what is known about inhibition in autism. Previous evidence of atypical inhibition in autism provided the rationale for the present study; this literature will be reviewed before the present study is introduced.

The autistic disorders

Autism is the most extreme form of a spectrum of disorders referred to as the pervasive developmental disorders. It is a lifelong disorder that affects functioning in cognitive, social, and affective domains (American Psychiatric Association [APA], 1987, 1994). The degree of impairment can vary greatly across individuals, but certain functional deficits are characteristic of all those with autism. Perhaps the most striking attribute of the autistic individual is his or her lack of interest in the social world. In fact, autistic people can seem completely unaware of the thoughts, needs, and feelings of other people; they may seem unaware that other people even exist. Parents of autistic children comment on their aloofness and inaccessibility, often believing that their children might be blind or deaf. The slamming of a door may not be registered by an autistic child, while a faint whisper may cause screaming. Children with autism respond to their environment in an inconsistent and unpredictable manner.

Children with autism fail to use their parents as social references by showing them new toys and looking back and forth between their parents and a shared object (Mundy, 1995). The absence of early joint attentional behaviors such as these may undermine the development of secure attachment relationships between parents and their autistic children. Even in times of distress, an autistic child will seem unaware of his or her own mother and avoid seeking comfort. Generally, individuals with autism avert eye contact and rarely initiate conversation. Language is typically delayed or absent, and conversational skills are awkward and unusual. Instead of playing games with their peers, children with autism prefer to sit by themselves, remaining unengaged or manipulating a toy in a repetitive, stereotyped manner. Thus it is often said that people with autism are locked inside a distant world very different from our own.

The autistic individual fails to develop complex interpersonal relationships; there is an incapacity for "a meeting of hearts and minds," as Hobson (1993, p.3) eloquently states. Not only are people with autism unaware that other people have thoughts, feelings, and beliefs, they also appear to lack a sense of self. Individuals with autism tend to refer to themselves in the third person, talking about themselves with detachment. Their conversation is limited to events and objects, and they avoid topics such as feelings, attitudes, and relationships. It appears that individuals with autism have extreme difficulty recognizing their role in the world and their relationship with other people. Since autistic children rarely (if ever) request the companionship of others, rarely (if ever) engage in appropriate conversation, rarely express emotion, and rarely (if ever) recognize the feelings of other people, they are unable to participate in basic, mutual, human relationships.

In addition to the severe social-communicative impairments characteristic of autism, the majority of autistic individuals are cognitively impaired (Bryson, Clark, & Smith, 1988). Even those without mental handicap display concrete, inflexible thought patterns, as well as obsessive, ritualistic behavior and insistence on order and sameness. As previously mentioned, both receptive and expressive language are typically delayed or absent. Imitative abilities are also impaired; for instance, the autistic individual may repeat things he/she hears in a very mechanical and inappropriate manner. A lack of symbolic play behavior indicates that representational thought is delayed or lacking in autistic individuals (Sigman, 1994). It bears emphasizing that the social and cognitive impairments in autism differ greatly across individuals; a high-functioning autistic person of normal intelligence might have some awareness of others and some basic communicative skills, while a low-functioning autistic person might have severe mental handicap, no awareness of others, and a general inability to function independently. Despite accumulating evidence on behavioral treatments that may help reinforce appropriate language and behavior, the prognosis remains poor for most autistic individuals (Lotter, 1974).

Attention in autism. Recent research on autism has focused on the development of attention. Lovaas and his colleagues coined the term "stimulus overselectivity" to describe the attentional behavior of autistic children. Lovaas, Schreibman, Koegel, and Rehm (1971) presented autistic and normally developing children with stimuli in three modalities: visual (red floodlight), auditory (white noise), and tactile (pressure cuff). The stimuli were presented singly, with an equal chance of being presented in the visual, auditory, or tactile modality. Participants were reinforced for responding during the presentation of any of the three target stimuli. It was found that the autistic children responded to a stimulus in only one modality, ignoring the other modalities, while the control group responded equally to all of the stimuli. When only one stimulus was presented in one modality, however, the autistic participants were able to respond successfully. Lovaas et al. concluded that autistic children tend to direct their attention to a restricted area of their surroundings. Thus only part of a stimulus, or even an irrelevant feature in the environment, may be the focus of attention at the expense of other features.

More recent research on autism has supported the claim of stimulus overselectivity across modalities. Casey, Gordon, Mannheim, and Rumsey (1993) tested the attentional abilities of ten adult men with pervasive developmental disorders and savant abilities in the form of exceptional calendar-calculating skills. Seven of the savants were diagnosed as autistic, and the remaining three participants were diagnosed with a related pervasive developmental disorder. In one of their studies, Casey et al. measured the performance of these participants on a test of divided selective attention. During this task, participants responded manually to target stimuli in two modalities. A random visual target (letter) and a random auditory target (tone) were presented simultaneously. The savant participants detected both visual and auditory targets less frequently than the control group. Like Lovaas et al. (1971), Casey et al. describe how the savant participants became overfocused in one modality, ignoring the other modality completely. It was possible, however, for a savant participant to start responding in the other modality, given enough trials. Casey et al. concluded that autistic individuals are capable of focusing and sustaining visual attention on a given task, but they have difficulty disengaging from a salient stimulus in order to attend to a stimulus in a different modality.

Evidence for a narrowed focus of attention also comes from studies that have examined attentional abilities within a modality. Findings suggest that individuals with autism may be excessively focused and resistant to disengaging and/or shifting across visual space. In a study conducted by Rincover and Ducharme (1987), twelve-year-old children with autism and a mental age-matched control group responded to stimuli that had either two spatially connected features or two spatially separate features. The features (colour and form) were presented as integral dimensions of the target stimulus (within-stimulus condition) or they were presented adjacent to each other (extra-stimulus condition). Thus the extra-stimulus condition consisted of the black outline of a form with a strip of colour immediately above this form. In comparison with the control group, the autistic children tended to exhibit overselectivity during the extra-stimulus condition, but not during the within-stimulus condition. Unlike the normal controls, the children with autism focused on one of the stimulus dimensions (form) at the expense of the other dimension (colour) when these dimensions were spatially separate. Additional evidence from generalization gradients indicated that this overselectivity did not operate in an all-or-none fashion. Instead, features to either side of the focal point were processed to a lesser degree. By increasing the distance between stimulus features, Rincover and Ducharme highlighted the tendency of autistic individuals to concentrate on restricted regions of the visual field at the cost of ignoring information outside of this region. The authors concluded that individuals with autism possess a type of 'tunnel vision.' Thus people with autism are competent at focusing on a particular object, but their region of focus is so narrow that other peripheral features may not be processed.

Casey et al. (1993) also employed a visual-spatial orienting task as an additional component of their study involving the autistic savant adults. Participants were required to respond manually to a target presented in the right or left visual periphery. A cue was presented at the location where the target would appear (valid cue) or at the opposite location (invalid cue). Overall, the savant participants showed longer reaction times than a normal control group on the spatial attention task, especially when the cue was invalid. The adults with autism required more time to disengage and/or shift their attention across space than the control group. However, when tested on a visual discrimination task that involved only one location, the performance of the savant participants was comparable to that of the control group. Casey et al. concluded that there is a selective impairment in visual-spatial orienting in autism.

In a similar study, Wainwright-Sharp and Bryson (1993) measured the manual responses of eleven autistic male adults to a validly or invalidly cued target presented to the right or left visual field. The cue consisted of an arrow presented in the centre of fixation, pointing in the direction of the upcoming target (valid) or in the opposite direction (invalid). The duration of the delay between the cue and the target (cue-target delay) was also varied. For cue-target delays of all durations, valid cues decreased the response times of the normal control group. Attention could be appropriately focused on the target location with the presentation of a valid cue, allowing for faster responses. However, the performance of the autistic participants did not improve when valid cues were presented with brief cue-target delays. Indeed, with brief cue-target delays, the cues had no effect on the performance of the autistic participants, suggesting that there was insufficient time to process and/or orient to the cues (Wainwright-Sharp & Bryson, 1993). During longer cue-target delays, the autistic participants had difficulty disengaging and/or shifting attention from one location (where they expected the target to appear) to engage attention in a new location (where the target really did appear), thus replicating the findings of Casey et al. (1993).

Evidence for difficulty disengaging and/or shifting also comes from a second study by Wainwright and Bryson (1996). A cue was presented in the centre of the visual field to inform the participant when, but not where, the target was about to appear. Ten high-functioning autistic adults and two comparison groups (chronological- and mental age-matched normal controls) detected targets in the right or left periphery, or targets presented centrally. Responses of the autistic participants to central stimuli were (nonsignificantly) faster than their responses to lateral stimuli, while the chronological age-matched controls responded more quickly to lateral than to central stimuli and the mental age-matched controls showed no central-lateral difference in response times. The autistic participants were focused on the central fixation point and therefore were efficient at subsequently responding to this same location, but inefficient at shifting their attention to a different spatial location. This effect was even greater when the task demands were increased such that identification rather than detection alone was required. Participants now had to identify one of two stimuli presented at, or to either side of, the point of fixation. Both of the control groups exhibited no differences in response times toward central and lateral targets. In contrast, the participants with autism responded more quickly to central than to lateral targets when the task required identification as well as detection.

Difficulties in mentally disengaging from a stimulus have also been reported using modified deception paradigms. Hughes and Russell (1993) questioned the validity of using deception tasks with autistic participants. Standard deception tasks are intended to measure participants' abilities to deceive others, an ability that relies on an awareness that other people have minds. These tests typically require that the participant show the experimenter where an object (toy or candy) is *not* hidden, so that the experimenter will be fooled and the participant can retrieve the prize for his or her own personal gain.

People with autism notoriously fail theory-of-mind tasks (Baron-Cohen, 1989, 1991; Baron-Cohen, Leslie, & Frith, 1985; Leslie & Frith, 1988). Hughes and Russell argued, however, that autistic children may have difficulty with the behavioral strategy necessary for such tasks, and that this difficulty may confound any difficulties with deception in itself. The tasks require participants to disengage attention from a salient object and point to a place where there is no object. As discussed, mental disengagement from an object may be a problem in autism. Hughes and Russell, therefore, removed the deceptive element from the task to see if autistic children still experienced difficulty.

In the task designed by Hughes and Russell (1993), the experimenter was no longer a competitor for the candy and did not receive the candy if the participants failed to correctly deceive. Sixty thirteen-year-old autistic children and sixty mentally handicapped children matched on mental age participated in the study. The autistic participants continued to perseverate in their incorrect responses, even when the deceptive element was removed. The authors concluded that autistic individuals have extreme difficulty disengaging their attention from a salient object. Difficulty in mentally disengaging from a stimulus is usually evidenced by the perseveration of a previous response. Individuals with autism tend to continue responding to a previous target stimulus or location instead of disengaging and/or shifting their response to a new target stimulus or location as per task instructions.

In a series of pivotal studies, Courchesne and his colleagues investigated the neurophysiological correlates of the behavioral responses of autistic individuals to stimuli presented across modalities (Ciesielski, Courchesne, Akshoomoff, & Elmasian, 1990; Ciesielski, Courchesne, & Elmasian, 1990; Ciesielski, Courchesne, & Elmasian, in press; Courchesne, Townsend, Akshoomoff, Yeung-Courchesne, Press, Murakami et al., 1994). Event-related brain potentials (ERPs) and behavioral responses were measured as autistic adults selected and manually responded to rare auditory and visual stimuli. Two stimuli were presented in each modality, one of which appeared rarely and the other frequently. The rarely presented stimulus was considered the target stimulus for that modality. The visual stimuli consisted of red and green flashes, and the auditory stimuli were high and low tones. Stimuli in both modalities were intermixed, and presented successively at unpredictable intervals. There were two major tasks: the focused attention task and the shift attention task. Both tasks required participants to attend to the correct modality, discriminate between stimuli, and organize a motor response. During the focused attention task, participants were required to press a button when they detected the target stimulus in one modality (either visual or auditory), while ignoring the stimuli in the other modality. During the shift attention task, participants were required to press a button when they detected a target stimulus in one modality, and correct target detection in one modality was a signal to shift attention to the stimuli in the other modality. Thus, a participant would correctly detect a visual target, and then shift attention to the auditory modality. Once the auditory target had been successfully detected, attention would then be shifted back to the visual target. The shift attention task required that participants inhibit or disengage their attention from one modality and reengage their attention to the other modality as quickly as possible.

The behavioral results of the study by Ciesielski, Courchesne, and Elmasian (1990) indicate that, compared to chronological- and mental age-matched controls, the adults with autism were successful at detecting the rare target stimulus during the focus attention task. Despite the competent performance of the autistic group on this task, however, neurological evidence pointed to abnormal ERP activity. Specifically, in comparison to the control groups, adults with autism did not display augmented ERP responses at frontal and posterior electrode sites. Frontal negative difference waves, absent in the ERP-recordings of the autistic participants, represent activity in the frontal cortex thought to be responsible for stimulus selection (Ciesielski, Courchesne, & Elmasian, 1990).

Ciesielski et al. (1990) suggest that individuals with autism may be neurophysiologically different from nonimpaired individuals, and/or that they may use different selective mechanisms when they do attend to a stimulus. Due to the simplicity of Ciesielski et al.'s focus attention task, the individuals with autism may have used compensatory mechanisms to attend to the stimuli. It is conceivable that this performance might weaken when faced with a more difficult task (such as the shift attention task). The autistic participants in Ciesielski et al.'s task did experience difficulty with the shift attention task, as revealed by elevated false alarm rates. Perseveration of a response was registered as a false alarm. For example, participants would continue to erroneously respond in the visual modality even though they had been signaled to shift to the auditory modality. This, coupled with the absence of ERP activity in the frontal cortices of the autistic participants and diminished ERP responses at posterior electrode sites, was taken as evidence for an inability to successfully disengage attention following a signal to shift attention.

In summary, the available evidence indicates that individuals with autism possess narrow selection abilities that 'overfocus' their attention (Lovaas et al., 1971; Rincover & Ducharme, 1987; Wainwright & Bryson, 1996), and have difficulty disengaging and/or shifting their attention both within and across modalities (Casey et al., 1993; Courchesne et al., 1994; Hughes & Russell, 1993; Wainwright-Sharp & Bryson, 1993). Courchesne and his colleagues raise some important considerations regarding the performance of individuals with autism on shift attention tasks. They contend that laboratory tasks requiring attentional shifts may even underestimate the severity of the attention problem in autism. The everyday world is much more complex, demanding, fast-paced and unpredictable than a training session in a laboratory environment. Courchesne et al. note further that impairment in shifting attention could greatly impede development in several areas of life, including social, affective, and cognitive domains. Such considerations underscore the importance of evaluating the development of selective attention in autism in the context of normal development.

The normal development of attention

Developmental literature suggests that the attentional abilities of young, nonimpaired children parallel those of autistic individuals. Perseveration of a response, indicating a failure to disengage from a stimulus, has been found in the problem-solving behavior of very young normal children. During a card sort task, Zelazo, Frye, and Rapus (1996) asked 3- and 4-year-olds to sort cards by either colour or shape (preswitch rules), and then reversed the instructions and asked the children to sort cards by the other dimension (postswitch rules). The main finding was that 60 percent of 3-year-olds continued to use preswitch rules on postswitch trials, whereas 90 percent of 4-year-olds successfully applied the postswitch rules.

Another paradigm, the A$\overline{B}$ task, has been used to measure the problem-solving abilities of even younger children. This task involves hiding an object at one of two locations (A) while the child watches, imposing a brief delay, and then allowing the child to search for the object. During the second trial, the object is visibly moved to the other location (from A to B) and, after a delay, the child searches again. Infants of 7 ½ to 12 months will incorrectly continue to search at A, the first hiding place (Diamond, 1985; Diamond, Cruttenden, & Neiderman, 1994; Harris, 1973). Diamond (1988) reports that perseverative errors emerge in older children with longer delays between the hiding phase and the search phase. Specifically, 12-month-old infants require 10-second delays, 9-month-old infants require 5-second delays, and 7 ½ to 8-month-old children require 2-second delays. Infants will search correctly if the delay criterion is reduced, suggesting that memory factors contribute to performance.

Perseverative responses in young children have been explained by three main developmental accounts: 1) the inability of young children to apply conditional rules to new situations, a failure related to immature behavioral control and cognitive inflexibility (Ozonoff, Strayer, McMahon, & Filloux, 1994; Zelazo et al., 1996; Zelazo, Reznick, & Pinon, 1995); 2) young children's greater susceptibility to proactive interference in short term memory (Harris, 1973); and 3) the immature functioning of both memory and inhibitory control in young children (Diamond et al., 1994).

A multiple-location $A\overline{B}$ experiment designed by Diamond et al. (1994) implicates inhibitory mechanisms in children's perseverative errors. Instead of two hiding places, children faced a semicircle of seven possible hiding places (wells). An object was first hidden in well #2 (A) and then at well #5 (B). Diamond and her colleagues reasoned that if children's perseverative errors are due to memory capabilities alone, then they should make more incorrect reaches to the wells on either side of B (wells #4 and #6), as they try to remember the location of the well. If children's perseverative errors are due to memory capabilities and inhibition, then they should make incorrect reaches to the wells between A and B (wells #4 and #3), as they try to remember the correct location *and* are pulled back to respond at A. It was found that the errors of 9 ½ to 10-month-old infants occurred more frequently at the wells between A and B than at the wells surrounding B. In order to make a correct response on the $A\overline{B}$ task, infants must not only remember where the object was last hidden, but they also must inhibit the tendency to continue responding at the previously correct location (Diamond et al., 1994). Baillargeon, DeVos, and Graber (1989) provide further evidence for the claim that memory mechanisms may be necessary but not sufficient to explain the $A\overline{B}$ error. In a non-search $A\overline{B}$ task, they demonstrated that 8-month-old infants can keep track of and remember changes in an object's hiding place, despite inadequate performance on search tasks (Baillargeon et al., 1989).

Inhibition in normal development. The study by Diamond et al. (1994) has illustrated that inhibition may be an important component of selective attention. Achieving attentional focus toward a particular aspect of the environment would appear to involve the ability to successfully ignore extraneous 'noise' in the periphery, as well as the successful cessation of prepotent responses. Early theorists reasoned that irrelevant stimuli elicit excitatory internal representations that compete with, and are gradually overcome by, increasing excitation toward the intended focal point (Broadbent, 1958; Lowe, 1979). These accounts view excitation as the only component of selective attention. In contrast, recent theorists suggest that selective attention is also dependent upon inhibitory mechanisms (Neill, 1977; Tipper, 1985; Tipper & Cranston, 1985; Tipper, MacQueen, & Brehaut, 1988). Excitatory mechanisms create a focal 'spotlight' of attention, while inhibitory mechanisms serve to actively ignore irrelevant stimuli. According to this account, features of the peripheral environment do not eventually 'lose' their salience for the observer; instead, inhibition is an active process that contributes to the efficacy of focused attention. Evidence indicates that the ability to successfully inhibit irrelevant features of the environment develops with age (Day & Stone, 1980; Lane & Pearson, 1982; Pick, Christy, & Frankel, 1972; Smith, Kempel, & Aronfeed, 1975; Tipper et al., 1989).

Different kinds of inhibition have been identified in the literature; two of these types of inhibition are negative priming and response inhibition. The main difference between negative priming and response inhibition is what is being inhibited. Negative priming measures built-up inhibition toward a feature of a distractor stimulus, while response inhibition measures built-up inhibition of a response. Evidence for active inhibition toward a stimulus is provided by studies that demonstrate negative priming effects. Negative priming is defined by an increase in reaction time toward a target stimulus when the same stimulus and/or location was previously ignored (Tipper, 1985). Inhibition associated with a distractor stimulus during an initial (prime) trial tends to slow subsequent responding toward this stimulus during the following (probe) trial. It is difficult to overcome the tendency to inhibit. A negative priming effect indicates that initial inhibition occurred, because it suggests that one needs to overcome this inhibition before responding.

As Tipper and his colleagues contend, negative priming effects provide evidence for *active* inhibitory mechanisms that work to ignore distractor stimuli. In a study that examined selection and negative priming as a function of cognitive failure (everyday absent-mindedness and failures of attention), Tipper and Baylis (1987) found evidence that negative priming is associated with efficient selection abilities. Only those participants with low measures of cognitive failure displayed negative priming effects and were also more efficient selectors than those participants with high measures of cognitive failure. Negative priming effects (increased response times due to the need to overcome inhibition) appear to be the cost associated with efficient selection. As children grow older, they become more competent selectors and they begin to manifest negative priming effects due to their greater inhibitory abilities (Tipper et al., 1989).

Unlike negative priming tasks, the measurement of response inhibition involves the presentation of a distractor alone, with no target: the participant must inhibit responding altogether (versus responding to a target while inhibiting a distractor stimulus, as in negative priming). During the initial prime trial, the distractor stimulus alone is presented and the participant must inhibit a response. Immediately following, during the probe trial, the target is presented in the same location as the distractor on the prime trial. Now participants must overcome their built-up inhibition to that specific location, as evidenced by increased response latencies.

In the case of negative priming, some tasks involve responding to a target stimulus that is superimposed over a distractor stimulus (Tipper, 1985; Tipper & Cranston, 1985). However, the majority of negative priming studies employ location tasks to study the spatial component of attentional abilities (Bryson, 1995; Hill, in prep.; Merrill, Cha, & Moore, 1994; Shapiro & Loughlin, 1993; Tipper et al., 1988; Tipper, Weaver, Kirkpatrick, & Lewis, 1991). In such paradigms, both the target and distractor stimuli are presented simultaneously at different locations. The initial prime phase of a spatial attention task involves ignoring a distractor stimulus at one location while responding to a target stimulus at another location. In the negative priming (probe) phase of these experiments, the target stimulus appears in the same position as the previous distractor stimulus. The few studies that demonstrate response inhibition also utilize spatial tasks (Bryson, 1995; Diamond et al., 1994; Hill, in prep.).

Spatial tasks sometimes present problems because it is difficult to determine exactly what is being inhibited. Is the object inhibited, or the location of the object inhibited? This potential confound has been examined by Tipper and his colleagues, and it appears that the behavioral goal of the task determines what will be inhibited (Tipper, Weaver, & Houghton, 1994; Milliken, Tipper, & Weaver, 1994). If a participant is searching for the location of a target, then the location of a distractor will potentially compete for a response and will therefore be inhibited. If the identity of a target is crucial, then the identity of the distractor (or a component of the identity that is similar to the target, such as colour) will be inhibited. In other words, inhibition is associated with a potentially competing response toward some representational property of the distractor (Tipper & Cranston, 1985; Tipper et al., 1988; Tipper, Weaver, & Houghton, 1994). Similarly, when participants are required to look for semantic information, then only the semantic properties of the distractor are inhibited (Tipper & Driver, 1988; Tipper et al., 1988). When spatial responses are required, inhibition becomes associated with location (Tipper et al., 1994; Milliken et al., 1994) or action-centred representations (Tipper, Lortie, & Baylis, 1992). Inhibition does not appear to be affected by response modalities (Tipper et al., 1988).

Inhibition of some representational property of the distractor is not to be confused with the response inhibition that occurs when a goal-directed response toward a target is actively withheld. Instead, inhibition of a distractor can be viewed as the inhibition of other possible behaviors toward this distractor or toward some aspect of this distractor. If these other behaviors were not inhibited or controlled, then the selection of a specific goal-directed behavior would be inefficient. Inhibition of a distractor can become more complicated with increasing task demands, resulting in the inhibition of multiple features of the distractor. Furthermore, Shapiro and Loughlin (1993) point out that the location of an object may always be inhibited, even if the goal of the task is to search for the colour or identity of an object. This may occur because location information forms part of the total object identity. It is necessary to locate an object in space before determining its identity. Since people with autism seem to possess a narrow visual focus while disregarding information in peripheral space (Lovaas et al., 1971; Rincover & Ducharme, 1987), it may be that they experience difficulty locating an object in space. Recall that adults with autism are able to successfully discriminate between objects appearing at one location, but display unusual delays when required to disengage and/or shift their attention to objects appearing at different locations in space (Casey et al., 1993). Spatial attention is an important ability that appears to be deficient in individuals with autism (Bryson, Wainwright-Sharp, & Smith, 1990; Casey et al., 1993; Wainwright & Bryson, 1995). Thus it becomes critical to minimize any potential confound between location and identity when examining selective attention in autism, and presumably in normal development as well.

Inhibition in autism

Unfortunately, few studies have been conducted that measure inhibition within the autistic population. The available evidence indicates that the performance of autistic individuals on negative priming tasks is comparable to the performance of normal control groups (Bryson, 1995; Hill, in prep.). In contrast, a large performance difference between autistic and normal control groups has been reported on tasks requiring response inhibition (Bryson, 1995; Hill, in prep.). High-functioning autistic adults responded approximately eight times more slowly than a control group during a response inhibition task (Hill, in prep.). The response inhibition task does not require participants to shift attention in space; rather, participants respond to a target stimulus across many trials. On some of these trials, a distractor stimulus is presented alone, without the presentation of a target stimulus. The participant must suddenly withhold a response, and then, on the next (probe) trial, respond to the target stimulus presented in the location previously occupied by the distractor. Withholding a response to the same (vs. a different) location interfered remarkably with the subsequent performance of the autistic participants, a result suggesting that individuals with autism may experience increased inhibition under some circumstances (Bryson, 1995; Hill, in prep).

Why would individuals with autism experience more difficulty during response inhibition tasks than during spatial negative priming tasks? It has been argued that response inhibition is a more active process than negative priming (Bryson, 1995). Response inhibition involves withholding a focused, goal-directed response toward a particular location, whereas negative priming involves responding to one stimulus while ignoring another. The inhibition of a response may require more powerful and active inhibitory mechanisms than the inhibition of a distracting stimulus.

People with autism display unusually long latencies when trying to respond to a previously inhibited location (Bryson, 1995; Hill, in prep., Ozonoff et al., 1994), a finding that suggests enhanced response inhibition. They also tend to perseverate on prepotent responses, in a manner very similar to the behavior of young children (Courchesne et al., 1994; Hughes & Russell, 1993; Ozonoff, et al., 1994). These two findings seem to contradict one another: how can inhibition be enhanced in autism, as shown through response inhibition tasks, if perseverative responding also occurs?

Perseveration of a response would suggest that there is difficulty inhibiting a prepotent response, which may be related to the inability to disengage and/or shift attention. One possibility is that individuals with autism may function attentively at a level similar to young normal children, who also are unable to inhibit previous responses. Alternatively, attention in autism may be characteristically different from attention in young childhood. An inability to inhibit previous responses in autism may occur concurrently with 'tunnel vision,' a tendency to 'over-inhibit' features outside a limited range of focus. In normal development, the ability to inhibit intruding environmental 'noise' strengthens with age: older children are better inhibitors than younger children (Day & Stone, 1980; Lane & Pearson, 1982; Pick, Christy, & Frankel, 1972; Smith, Kempel, & Aronfeed, 1975; Tipper et al., 1989). Perseverative responding in autism might be explained by an inability to inhibit prepotent responses, and/or enhanced inhibition of alternate locations and responses.

The study by Ciesielski, Courchesne, and Elmasian (1990) measured the ability of autistic adults to respond to stimuli in a single modality (visual or auditory) and their ability to shift their responses between modalities. Both visual and auditory stimuli were presented simultaneously at different intervals in time. During the shift task, participants responded to the target stimulus in a particular modality (e.g., visual) only after making a correct response in the other modality (e.g., auditory). As discussed earlier, the results showed that the autistic participants could successfully focus on a stimulus presented in one modality, but had difficulty disengaging and shifting attention across modalities. Considering the developmental literature on inhibition, it may be that this finding occurred due to differences in the inhibitory processes of autistic and normal individuals. The popular explanation is that autistic individuals experience difficulty inhibiting prepotent responses. An alternate hypothesis is that there is a selective impairment in visual-spatial attention in autism, resulting in both overfocused attention and enhanced spatial inhibition (Bryson, 1995). Such an impairment would enable an autistic person to focus on a small part of a stimulus array while completely ignoring other features in the periphery. If individuals with autism possess enhanced inhibition, then potential responses to an alternate location would be inhibited, resulting in perseveration of a response. This enhanced inhibition would also interfere with the ability to flexibly disengage and/or shift attention. In short, then, both exaggerated response inhibition and perseveration of responses may be due to enhanced inhibition in autism.

The present study

The main objective of this study was to measure the development of visual selection and inhibition in typically developing children and in children with autism. It is hoped that this study might contribute to our understanding of the normal development of inhibition and to claims about dysfunctional attention in autism. The task designed by Ciesielski, Courchesne, and Elmasian (1990) was modified for the purpose of measuring selection and inhibition within the visual modality.

As in the study by Ciesielski, Courchesne, and Elmasian (1990), the focus attention task, or prime phase of this experiment, was designed to measure selective attention abilities. In Ciesielski et al.'s (1990) task, coloured squares were presented briefly, one-at-a-time, on a computer screen. The target colour appeared randomly on one third of the trials, and a different distractor colour was presented on each of the remaining trials. Participants were asked to make a manual response every time they detected the target colour. Ciesielski et al. used this task (independently in both visual and auditory modalities) as a control measure for their shift task. The shift task was identical to the focus attention task except that participants were required to shift their attention to a stimulus in the other modality. Adults with autism were able to successfully respond to target stimuli in one modality, but experienced difficulty disengaging and shifting their attention between the visual and auditory modalities. One outstanding question is whether this finding reflects a cross-stimuli effect instead of a cross-modality effect. In addition, the task requirements of the shift task in the Ciesielski et al. study seem extremely demanding. Participants were required to select and respond to the target stimulus in one modality; when this was achieved, they were expected to shift to the other modality and select and respond to the target stimulus there. Four stimuli were presented in total (two in each modality), and participants had to discriminate, respond differentially, and shift between modalities.

The visual focus attention task designed by Ciesielski et al. (1990) was modified in the present study to measure attentional shift and inhibition within a modality. As in Ciesielski et al.'s visual focus attention task, two stimuli (target and distractor) were presented one-at-a-time in the visual modality alone. Instead of shifting attention across modalities, however, the test phases of this study required participants to shift attention across stimuli within the visual modality. Ciesielski et al. found that adults with autism experienced difficulty disengaging and/or shifting across modalities. The modified version of their paradigm was designed to measure the ability to disengage and/or shift between stimuli presented at one location within the visual modality.

There are three main advantages to this modified version of Ciesielski et al.'s (1990) timed Go-NoGo task. First, unlike negative priming or response inhibition tasks, the stimuli are all presented in the same location. This eliminates any potential confounding between location and identity. Inhibition associated with identity alone was examined in the present study. Secondly, responses are more actively withheld than during negative priming tasks. Since targets appeared at a fixed location, participants may become more focused during this task than during spatial tasks, and thus may experience greater inhibition associated with *not* responding to the distractor stimulus (as in response inhibition tasks; Hill, in prep.). Thirdly, the task employed here is much less complicated and less difficult than either negative priming tasks or the Ciesielski et al. cross-modality task. Task simplicity allows the measurement of attention in children with autism, not just adults. As well, errors in performance during a simple task might shed light on core deficits in basic attentional abilities.

Our task is very similar to the Go-NoGo task employed by Ozonoff et al. (1994), who measured the ability to selectively respond to one of two stimuli (neutral inhibition), the ability to inhibit a previous response and respond to the other stimulus (prepotent inhibition), and the ability to shift or alternate responses between the two stimuli (cognitive flexibility). Compared to MA-matched normal controls and a group of children with Tourette syndrome, children with autism performed well during the neutral inhibition condition, but had increased response latencies during the prepotent inhibition and cognitive flexibility conditions. The children with autism also perseverated more than the control groups during the cognitive flexibility condition, leading the authors to speculate that there may be a deficit in cognitive flexibility in autism (Ozonoff et al., 1994). However, the inferior performance during the prepotent inhibition condition suggests that in autism, inhibition may also be impaired. In any event, the children with autism in Ozonoff et al.'s study had difficulty shifting attention within one modality, not just across modalities, as found by Ciesielski et al. (1990).

Note further that the prepotent inhibition condition in the Ozonoff et al. (1994) study may have been actually measuring two different aspects of inhibition. Not only were participants required to inhibit a prepotent response, they were also required to shift their responses toward the previously ignored distractor stimulus. In other words, before responding efficiently toward this distractor, participants had to overcome their built-up inhibition. When target and distractor stimuli are reversed during attention tasks, inhibition of a prepotent response toward the previous target may be confounded by difficulty overcoming inhibition toward the previous distractor. The present study was designed to differentiate the relative roles of inhibiting a prepotent response and overcoming inhibition associated with a distractor stimulus. The cessation of inhibition toward a stimulus will be termed 'disinhibition.' Disinhibition, or the ability to overcome built-up inhibition, may greatly affect performance on tasks that measure the ability to successfully shift attention by inhibiting prepotent responses. Evidence of disinhibition would suggest an alternate inhibitory component that has been neglected in the existing literature on attention and its development or maldevelopment.

In the present study, the experimental conditions consisted of two phases: a prime phase and a test phase. Selective attention was measured during the prime phase, and a shift in attention was measured during the test phase. The main test phase was a Reversal condition, in which participants responded to the stimulus that they had previously ignored. For example, if a participant responded to red and ignored green during the prime phase, he or she then responded to green and ignored red during the test phase. This condition was identical to the "prepotent inhibition" condition in the Ozonoff et al. (1994) study, except that participants were required to distinguish between colours in this study, and between shapes (circle or square) in Ozonoff et al.'s study. The Reversal condition thus provided an attempt to replicate Ozonoff et al.'s finding that individuals with autism experience difficulty shifting within a modality. Additional conditions attempted to provide independent measures of why such difficulties might exist.

There are two main explanations for the finding that individuals with autism have difficulty shifting attention: 1) they experience difficulty inhibiting prepotent responses, as hypothesized in young normal, as well as in autistic, children (Courchesne et al., 1994; Diamond, 1988); and/or 2) they may experience difficulty responding to previously inhibited stimuli (disinhibition; Bryson, 1995). The Reversal condition reversed the roles of target and distractor stimuli and therefore involved both inhibiting a response *and* responding to a previously inhibited stimulus (disinhibition). Two additional conditions --Response Inhibition and Disinhibition--were developed in an attempt to independently examine these different aspects of inhibition. It was expected that the Response

Inhibition and Disinhibition conditions would shed light on the normal development of inhibition, as well as on the possible unique development of inhibition in autism.

During the Response Inhibition condition, participants responded to a new colour and were asked to ignore the previous target colour. For example, if a participant responded to red and ignored green during the prime phase, he or she responded to blue and ignored red during the test phase. The Response Inhibition condition thus provided a measure of the ability to inhibit a response toward a target stimulus. During the Disinhibition condition, participants responded to the colour that they had previously ignored, and ignored a new colour. If a participant responded to red and ignored green during the prime phase, he or she then responded to green and ignored blue during the test phase. The Disinhibition condition thus provided an independent measure of the ability to overcome inhibition associated with a distractor stimulus.

There were thus three conditions in all, each preceded by the same prime phase: 1) Reversal condition, 2) Prepotent Inhibition condition, and 3) Disinhibition condition (see Figure 1). The development of these attentional processes were examined in 5- and 7-year-old normal children, and in a group of 12-year-old children with autism. The children with autism were individually matched to the typically developing children on their baseline (prime phase) reaction times during the basic selective attention task.

Expected results. It was predicted that the autistic participants would experience more difficulty than the control children during the Reversal condition. The Reversal condition requires participants to inhibit their responses toward the previous target colour *and* to respond to the previously inhibited distractor colour. Research to date using the

Prime Phase

Target	Distractor
RED	GREEN

Probe Phase

Condition	Target	Distractor
Reversal	GREEN	RED
Prepotent Inhibition	BLUE	RED
Disinhibition	GREEN	BLUE

Figure 1. The Go-NoGo visual selective attention task. Participants were required to respond to the sequentially presented target colour and ignore the distractor colour across trials. The target was presented on 20 of the 60 trials during each phase. The prime phase remained identical for all conditions, and the prime and probe phases were yoked. The prime phase target colour (red or green) was counterbalanced across participants. Conditions were counterbalanced across 3 days.

same paradigm (Ozonoff et al., 1994) indicates that individuals with autism have difficulty shifting between stimuli presented at one location within the visual modality. Thus it was expected that in the Reversal condition, children with autism would display longer reaction times and would perseverate more (as evidenced by elevated false alarm rates) than the control group.

A major question of interest is whether this predicted difficulty with the Reversal condition reflects difficulty inhibiting a prepotent response, or difficulty disinhibiting a previously inhibited response. The widely held view is that problems on such tasks are due to prepotent inhibition; that is, that there is difficulty inhibiting a prepotent response. However, evidence of enhanced inhibition in autism (Hill, in prep.) raises the alternate possibility that individuals with autism may have difficulty disinhibiting, or overcoming, a previously inhibited response. Thus the Prepotent Inhibition and Disinhibition conditions were designed to explore why individuals with autism may experience difficulty with the Reversal condition.

In comparison with negative priming tasks, this study's Disinhibition condition requires the inhibition of a distractor stimulus *without* the simultaneous response to a target stimulus. The distractor stimulus appears alone and no response is made. Quite possibly, the initial inhibition associated with the distractor may be greater during the present Disinhibition condition than during negative priming tasks, since a response has been withheld. Withholding a response has been associated with active inhibition (Hill, in prep.) It was predicted that autistic participants may experience particular difficulty with the Disinhibition condition due to enhanced inhibition associated with a previously withheld response.

Based on evidence that inhibition develops with age (Day & Stone, 1980; Lane & Pearson, 1982; Pick, Christy, & Frankel, 1972; Smith, Kempel, & Aronfeed, 1975; Tipper et al., 1989), it was expected that the 7-year-old normally developing children may exhibit greater inhibitory effects than the 5-year-old children. The development of inhibitory control across age might be evidenced as an increased ability of the 7-year-old children to respond flexibly and quickly during the probe phases of all conditions. Overall reaction times should decrease with age as children's motor responses become more efficient.

It was also expected that, due to a tendency to perseverate (Diamond, 1988), the 5-year-old children may make more false alarms than the 7-year-old children by continuing to respond to the previously correct target in the Reversal and Prepotent Inhibition conditions. Individuals with autism are also known to perseverate (Courchesne, 1994). This perseveration may occur directly because of the inability to inhibit a prepotent response (Reversal and Prepotent Inhibition conditions), or indirectly, since the inability to respond to a new stimulus may cause one to 'fall back' and respond to the previously correct stimulus (Reversal, Prepotent Inhibition, and Disinhibition condition). Thus elevated false alarm rates during the Disinhibition condition may reflect an inability to disinhibit a previously inhibited response.

To summarize, there were four main predictions: 1) It was expected that the children with autism would have more difficulty (i.e., increased RTs and false alarms) than the control group when required to simultaneously inhibit a prepotent response *and* disinhibit a distractor colour (Reversal condition); 2) The performance of the children with autism may be no different than that of the control group during the Prepotent Inhibition condition; 3) The children with autism were expected to display increased response times and false alarms relative to controls during the Disinhibition condition; 4) The older children would show evidence of greater inhibitory control than the younger children. It was expected that the present study would yield new insights on these and related issues. In particular, is the normal developmental course of inhibitory control comparable for both prepotent inhibition and disinhibition? And does the performance of children with autism parallel, or differ from, that of younger normal children? Are the attentional abilities of individuals with autism 'stuck' at a low developmental level, or the product of unique inhibitory functioning and perhaps enhanced inhibitory control?

Method

Participants

The participants of this study included two groups of typically developing children and a group of children with autism. Information letters and permission forms were sent to parents and no child was tested without parental consent. Parents reported that all children had normal colour vision and normal or corrected-to-normal acuity in both eyes.

Developmental group. Fifty-four typically developing children participated in this study: 28 5-year-olds ($\underline{M}$ = 67.7 months, $\underline{SD}$ = 3.3) and 26 7-year-olds ($\underline{M}$ = 91.9 months, $\underline{SD}$ = 5.0). Half of the children in each age group were female. After obtaining the approval of the Research Advisory Committee of the Durham Board of Education, the children were recruited from Cadarackque Public School in the Durham Board of Education, Ajax, Ontario. According to teacher reports, all of the children could be described as average 5- and 7-year-olds in terms of their academic and social progress at school. Table 1 provides descriptive data for the two groups of typically developing children.

Autistic group. Ten male children with autism, aged 10-14 years ($\underline{M}$ = 139.2 months, $\underline{SD}$ = 16.5), were recruited from Multiple Exceptionalities classes at Applecroft P.S., Cadarackque P.S., Fairport Beach P.S., Lincoln Alexander P.S., Kathleen Rowe Memorial P.S., and Sir John A. Macdonald P.S. in the Durham Board of Education (Pickering/Ajax/Whitby, Ontario). Children were also recruited during Saturday Friendship Clubs sponsored by Woodview Manor in Hamilton, Ontario. All had been

Table 1

Mean (sd) Ages, Verbal Scores, and Performance Scores for each Group of Typically Developing Children

Age Group	Sex	n	Age (Months)	Verbal (TACL-R) (raw score /120)	Performance (McCarthy) (raw score /33)
5	male	14	66.6 (3.0)	76.50 (13.08)	23.43 (2.79)
	female	14	68.6 (3.4)	81.71 (14.33)	24.00 (2.60)
	Total	28	67.6 (3.3)	79.11 (13.73)	23.71 (2.66)
7	male	13	91.6 (3.4)	90.85 (9.69)	26.15 (2.79)
	female	13	92.2 (6.3)	90.69 (8.12)	27.31 (1.60)
	Total	26	91.9 (5.0)	90.77 (8.76)	26.73 (2.31)

formally diagnosed as autistic according to DSM-III-R (APA, 1987) or DSM-IV (APA, 1994) criteria.

Children with autism were matched to children in the developmental group according to their average baseline response times during the prime phases of the experimental task. Matching between groups was also based on gender, order of presentation of conditions and assignment of target colour (red or green). Table 2 provides descriptive data, including baseline RTs on the experimental task, for the autistic group and the control group. All of the autistic children were relatively high-functioning, as indicated by their scores on standardized measures of nonverbal (subtests of the McCarthy Scales of Children's Abilities; McCarthy, 1972) and/or verbal skills (TACL-R; Carrow-Woolfolk, 1985). One child with autism did not complete the Disinhibition condition due to fatigue and therefore this child's data consists of only 2 conditions (Reversal and Prepotent Inhibition).

Design and Procedure

There were 3 experimental conditions in all: Reversal, Prepotent Inhibition, and Disinhibition (see Figure 1). Each of these conditions consisted of a prime phase (baseline) followed immediately by a probe phase (test). In each phase, squares of two different colours were presented on a computer screen one-at-a-time in sequence; the task required responses to one of the two different colours. The prime phase was the same across all conditions (e.g., target = red; nontarget = green). The probe phase differentiated the 3 conditions. In the Reversal condition, the roles of the target and nontarget (distractor) from the prime phase were reversed during the probe phase. If a

Table 2

Mean (sd) Ages, Baseline RT Scores, Verbal Scores, and Performance Scores for Autistic and Control Groups

Group	n	Age (Months)	Baseline RT (ms)	Verbal (TACL-R) (raw score /120)	Performance (McCarthy) (raw score /33)
Autistic	10	139.20 (16.49)	426.01 (82.54)	84.60 (23.92)	28.30 (3.06)
Control	10	78.50 (13.26)	441.35 (57.07)	84.80 (11.43)	25.30 (3.02)
Total	20	108.85 (34.38)	434.09 (68.69)	84.70 (18.24)	26.80 (3.33)

participant responded to red and ignored green during the prime phase, he or she then responded to green and ignored red during the test phase. Thus during the Reversal condition, participants were required to inhibit their previous responses to the target colour (prepotent inhibition) *and* respond to the previously inhibited distractor colour (disinhibition).

The Prepotent Inhibition and Disinhibition conditions each systematically tested only one of these task demands. The probe phase of the Prepotent Inhibition condition required the inhibition of the previous target response. Participants responded to a new target colour (blue) and inhibited the target colour (red/green) from the prime phase. During the probe phase of the Disinhibition condition, participants responded to the previously inhibited distractor colour (red/green) from the prime phase, and ignored a new colour (blue).

Participants were seated approximately 1 foot in front of a computer (386SX IBM-compatible PC with VGA 8" monitor), which controlled presentation of the stimuli and recorded response latencies. The stimuli were presented one-at-a-time in the centre of the screen, each for a duration of 90 msecs, with random interstimulus intervals of 1500-2500 msecs. There were 60 trials in each of the two phases (prime and probe): 20 target and 40 nontarget trials. Response times (in msecs) were recorded from the onset of each stimulus to the onset of a bar press. The target colour (red or green) was counterbalanced across participants in each group, such that half of the participants responded to red in the prime phase and the other half responded to green in the prime phase. Order of presentation of the 3 conditions was counterbalanced across children in each group according to a Latin square design. Participants completed the study across 3 days in order to control for practice or carry-over effects between conditions. Four of the 10 participants with autism completed all 3 conditions during one day, with breaks between each condition, due to time constraints when testing these participants. Each condition took approximately 5 minutes to complete.

Testing took place in a quiet room located near the children's classrooms in their schools. Some children (n = 2) were tested in quiet rooms within their homes. At the beginning of each prime phase, participants were told that they would be playing a game in which they had to press the space bar every time they saw a *red* square (target colour) appear on the monitor. A coloured sticker corresponding to the target colour was placed on the space bar. Participants were instructed to press the space bar as soon as they saw the target colour. At the beginning of the probe phase, modified instructions were given dependent on the condition. For example, at the beginning of the probe phase of the Reversal condition, the experimenter said, "Now we will be playing a new game, the *green* game. For this game, you have to press the space bar as soon as you see the *green* square." Children were asked to repeat the instructions to make sure that they understood correctly. Immediately preceding each condition, participants practiced the prime phase of the game for 10 trials while the experimenter gave verbal reinforcement and repeated the instructions if necessary. Verbal reinforcement was not given during the prime and probe phases, but children were reinforced with a small prize, such as a sticker, at the end of each probe phase.

All participants received the Test of Auditory Comprehension of Language-Revised (TACL-R; Carrow-Woolfolk, 1985) and the Block Building, Puzzle Solving, and Tapping Sequence subtests from the McCarthy Scales of Children's Abilities (McCarthy, 1972). These tests of language abilities (verbal measure) and nonverbal problem-solving abilities (performance measure) took approximately 15 minutes to complete and were administered during each participant's final testing session.

Results

Analyses of the normal developmental data are presented first. This is followed by comparisons of autistic and matched normal children on the same tasks. In each case, reaction time (RT) and error data, consisting of false alarm rates and misses, are considered. Reaction time data consist of mean RTs (in ms) to the target stimulus (hits) during the prime and probe phases of each condition (Reversal, Prepotent Inhibition, and Disinhibition) for each participant. There were a possible 20 correct responses to targets out of a total of 60 trials for each of the prime and probe phases during each condition. Thus for the three conditions, two mean RTs (prime phase and probe phase) are reported for each group (see Table 3). False alarm data consist of the mean number of responses to the distractor stimulus during the prime and probe phases of each condition for each participant. Forty of the 60 trials during each of the prime and probe phases consisted of the presentation of a distractor stimulus, and if a response was made to it, then an error or a false alarm was recorded. For the three conditions, two mean false alarm rates (prime phase and probe phase) are reported for each group (see Table 4). Misses data consist of the mean number of times there was a failure to respond to the target stimulus during the prime and probe phases of each condition for each participant. Again, for each of the three conditions, two mean number of misses are reported (see Table 5).

Developmental data

An alpha level of .05 was used for all statistical tests unless otherwise specified. Post-hoc analyses of significant interactions were explored using t-tests for independent samples with the Bonferroni correction for Type 1 error rate.

Table 3

Mean RT in ms (sd) across Conditions

Group	n	Reversal		Prepotent Inhibition		Disinhibition	
		Prime	Probe	Prime	Probe	Prime	Probe
Age 5	28	560.08 (142.91)	643.62 (130.85)	522.89 (108.00)	604.79 (131.59)	555.00 (131.06)	654.70 (173.87)
Age 7	26	496.67 (109.96)	567.59 (120.09)	499.01 (113.43)	537.18 (92.47)	517.89 (100.18)	565.54 (126.98)
Autistic	10	438.36 (98.15)	496.62 (147.67)	399.83 (64.89)	421.63 (68.58)	436.77 (122.91)	486.57 (137.40)
Control	10	427.07 (68.69)	506.22 (80.87)	449.28 (71.30)	504.21 (88.92)	447.71 (87.72)	504.04 (94.70)

Table 4

Mean Number of False Alarms (sd) across Conditions

Group	n	Reversal		Prepotent Inhibition		Disinhibition	
		Prime	Probe	Prime	Probe	Prime	Probe
Age 5	28	5.54 (6.97)	6.75 (5.44)	5.54 (5.73)	5.14 (6.02)	6.93 (6.54)	5.14 (6.40)
Age 7	26	2.04 (2.69)	3.00 (4.12)	3.15 (3.80)	2.38 (3.32)	2.85 (3.26)	2.00 (2.67)
Autistic	10	3.01 (3.41)	4.10 (3.25)	3.80 (1.99)	2.90 (2.56)	10.44 (9.55)	6.78 (5.78)
Control	10	6.90 (9.53)	6.50 (6.17)	6.80 (5.98)	5.60 (4.53)	7.00 (6.72)	5.50 (7.28)

Table 5

Mean Number of Misses (sd) across Conditions

Group	n	Reversal		Prepotent Inhibition		Disinhibition	
		Prime	Probe	Prime	Probe	Prime	Probe
Age 5	28	1.21 (2.06)	2.07 (2.88)	1.18 (1.85)	1.25 (2.15)	1.04 (1.35)	2.46 (3.18)
Age 7	26	0.19 (0.49)	0.77 (1.14)	0.27 (0.53)	0.50 (0.91)	0.54 (1.17)	0.62 (1.24)
Autistic	10	0.80 (1.32)	1.00 (1.05)	1.50 (3.03)	1.30 (2.16)	2.00 (2.35)	0.67 (0.87)
Control	10	0.60 (0.84)	1.40 (3.17)	1.00 (1.89)	1.40 (2.01)	0.60 (1.26)	0.90 (1.29)

Reaction times. Each of the 6 distributions of mean RTs (one for each phase of each condition) approached normality, as determined by nonsignificant Kolmogorov-Smirnov values, and thus parametric analyses were used. Mean RTs were analyzed in a 2 x 2 x 3 x 2 (Age x Sex x Condition x Phase) repeated-measures MANOVA. Age (5 or 7 years of age) and Sex were the between-subjects factors, while Condition (Reversal, Prepotent Inhibition, Disinhibition) and Phase (prime, probe) were the within-subjects factors. The MANOVA revealed significant main effects for Age, F (1, 50) = 4.88, p = .03, Sex, F (1, 50) = 9.06, p = .004, Condition, F (2, 100) = 4.21, p = .02, and Phase, F (1, 50) = 66.21, p = .001. In addition, there was a significant Age x Phase interaction, F (1, 50) = 4.37, p = .04, but these two variables did not interact with Condition, F (2, 100) = .78, p = .46.

The main effects of Age and Sex indicated that the 7-year-olds (M = 530.65, SD = 97.47) responded significantly faster than the 5-year-olds (M = 590.18, SD = 112.63) and that the males (M = 520.81, SD = 112.55) responded significantly faster than the females (M = 602.22, SD = 89.65). The main effect of Phase revealed that, across conditions, mean RTs during the prime phases (M = 526.02, SD = 104.97) were significantly faster than mean RTs during the probe phases (M = 597.01, SD = 121.52). Post-hoc analysis of the significant Age x Phase interaction indicated that this prime-probe difference was obtained for both the 5-year-old age group, t (27) = 7.99, p = .001, and the 7-year-old age group, t (25) = 3.98, p = .001. However, the 7-year-olds (M = 556.77, SD = 105.40) responded significantly faster than the 5-year-olds (M = 634.37, SD = 125.27) during the probe phases, t (52) = 2.45, p = .02, but not during the prime phases, t (52) = 1.47, p =

.15. Figure 2 presents the mean RTs for each age group and phase averaged across conditions.

Post-hoc analysis of the significant main effect of Condition revealed that, collapsed across prime and probe phases, mean RTs during the Reversal condition (M = 568.28, SD = 119.26) were significantly longer than RTs during the Prepotent Inhibition condition (M = 541.81, SD = 106.63), t (53) = 2.35, p = .02, but not longer than RTs during the Disinhibition condition (M = 574.45, SD = 131.15), t (53) = .55, p = .58. Mean RTs during the Disinhibition condition were significantly longer than RTs during the Prepotent Inhibition condition, t (53) = 2.64, p = .01. Interpretation of the main effect of Condition is complicated by the nonsignificant Condition x Phase interaction, F (2, 100) = .59, p = .55.

The probe phases of the Prepotent Inhibition and Disinhibition conditions were designed in an attempt to explain performance difficulties within the Reversal condition. Due to the exploratory nature of this research, additional post-hoc RT analyses were performed to determine whether RTs during the prime and/or probe phases contributed to the main effect of Condition. Mean RTs from each phase were analyzed independently by two separate 2 x 2 x 3 (Age x Sex x Condition) repeated-measures ANOVAs. Age (5 or 7 years of age) and Sex were the between-subjects factors, while Condition (Reversal, Prepotent Inhibition, Disinhibition) was the within-subjects factor. The ANOVA for the prime phases revealed a significant main effect for Sex, F (1, 50) = 8.03, p = .01, as described above for both phases together. The main effects of Group (F (1, 50) = 2.40, p = .13) and Condition (F (2, 100) = 1.77, p = .18) were nonsignificant. In contrast, the

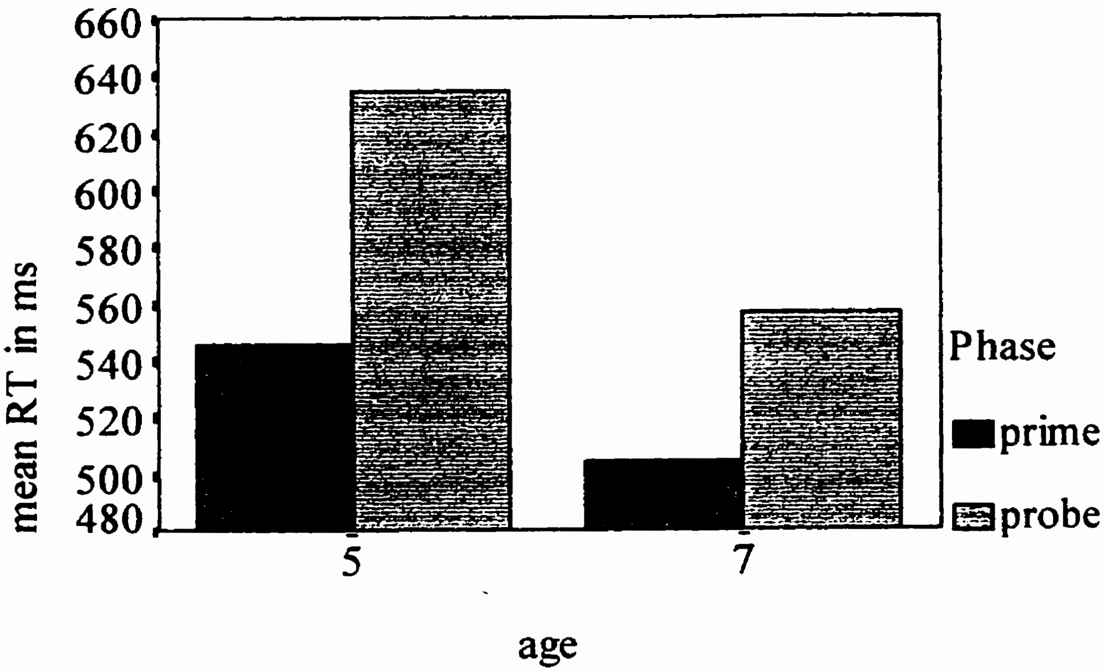
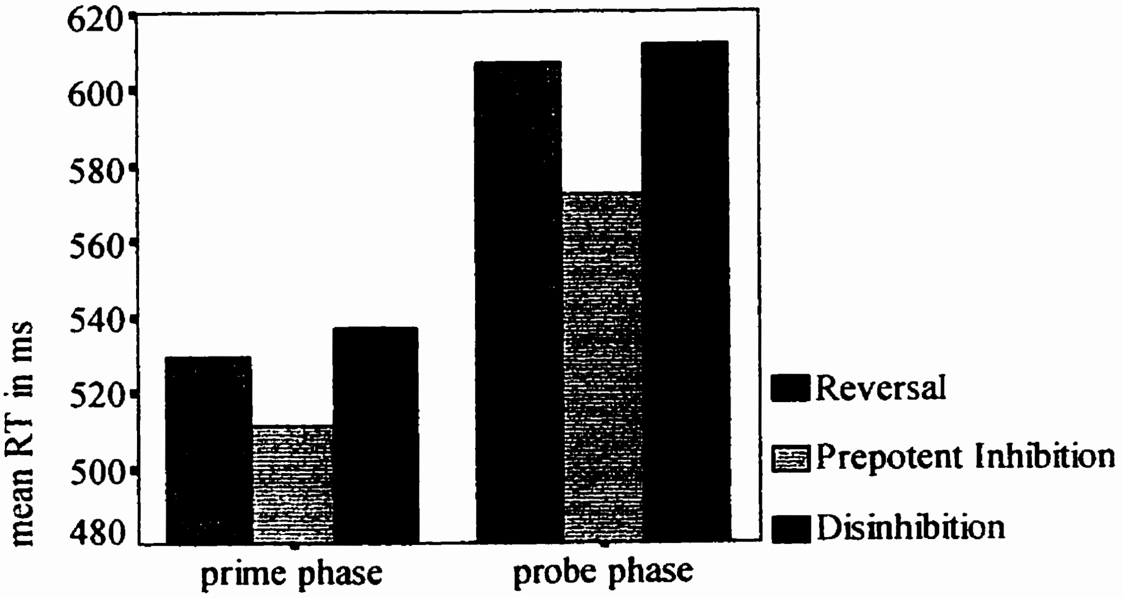


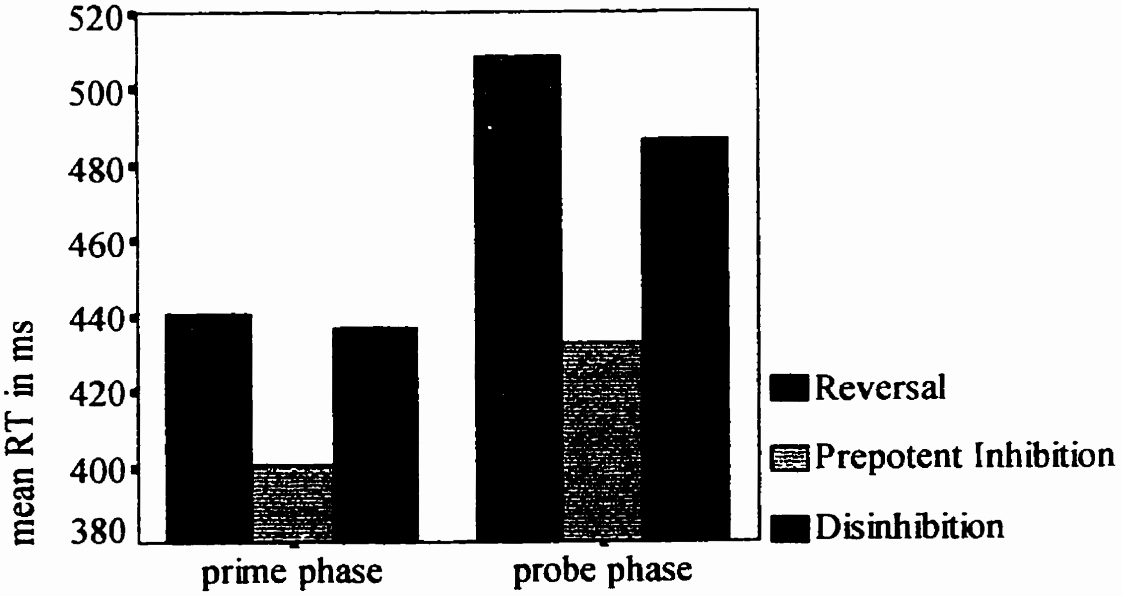
Figure 2. Age x Phase interaction for mean RTs by group and phase.

ANOVA for the probe phases revealed significant main effects for Group, F (1, 50) = 6.79, p = .01, and Condition, F (2, 100) = 4.05, p = .02, as well as Sex, F (1, 50) = 8.43, p = .01. The main effects for Group and Sex have been previously discussed. Analysis of the main effect of Condition revealed the same pattern of results exposed by the analysis of both phases together. During the probe phases, mean RTs during the Reversal condition (M = 607.02, SD = 130.37) were significantly longer than RTs during the Prepotent Inhibition condition (M = 572.24, SD = 118.40), t (53) = 2.68, p = .01, but not longer than RTs during the Disinhibition condition (M = 611.77, SD = 158.21), t (53) = .33, p = .74. Mean RTs during the Disinhibition condition were significantly longer than RTs during the Prepotent Inhibition condition, t (53) = 2.39, p = .02. Figure 3 presents the mean RTs for both age groups during the prime and probe phases of each condition.

To take into account the possibility of fatigue effects, overall mean RTs for the first and second half of the probe phases were analyzed in a 2 x 2 x 3 x 2 (Age x Sex x Condition x Block) repeated-measures MANOVA. Age (5 or 7 years of age) and Sex were the between-subjects factors, while Condition (Reversal, Prepotent Inhibition, Disinhibition) and Block (first 30 trials or last 30 trials of the probe phases) were the within-subjects factors. The MANOVA revealed significant main effects for Group, F (1, 50) = 8.57, p = .01, Sex, F (1, 50) = 6.22, p = .02, Condition, F (2, 100) = 4.26, p = .02, and Block, F (1, 50) = 10.07, p = .003. None of the interactions were significant. All of the significant effects have been described above in the analyses of both phases, except for the main effect of Block, which is described here. For both age groups, RTs



5- and 7-Year-Olds



Autistic Group

Figure 3. Mean RTs of each phase within each condition for 5- and 7-year-olds, and for the autistic group alone.

during the first half of the probe phases (M = 596.39, SD = 120.75) were significantly faster than RTs during the second half of the probe phases (M = 630.37, SD = 146.34) for all conditions combined.

The overall RTs of false alarms made by the 5-year-old children (M = 461.30, SD = 122.07) were significantly shorter than the RTs of their hits (M = 590.18, SD = 112.63), T (13) = -2.06, p = .04. The difference in RTs between false alarms and hits was not significant for the 7-year-old children, for both age groups considered together, or for males and females considered separately.

False alarm error rates. None of the 6 distributions of mean false alarm rates approached normality, as determined by significant Kolmogorov-Smirnov values, and thus nonparametric analyses (Mann-Whitney U tests and Wilcoxon Matched-Pairs Signed-Ranks tests) were used. An alpha level of .01 was used for these analyses, as calculated by the Bonferroni correction for Type 1 error rate.

Analyses of age differences in false alarm rates collapsed across prime and probe phases revealed that the 7-year-olds (M = 2.57, SD = 2.41) made fewer false alarms overall than the 5-year-olds (M = 5.84, SD = 5.24), U (54) = 212.5, p = .01. Specifically, the 7-year-olds (M = 2.52, SD = 2.65) made fewer false alarms than the 5-year-olds (M = 6.14, SD = 5.79) during the Reversal condition, U (54) = 202.0, p = .001. Parallel age differences in mean false alarm rates approached significance during the Disinhibition condition, U (54) = 224.5, p = .02. Figure 4 presents mean false alarm rates across phases made by the 5- and 7-year-olds during each condition.

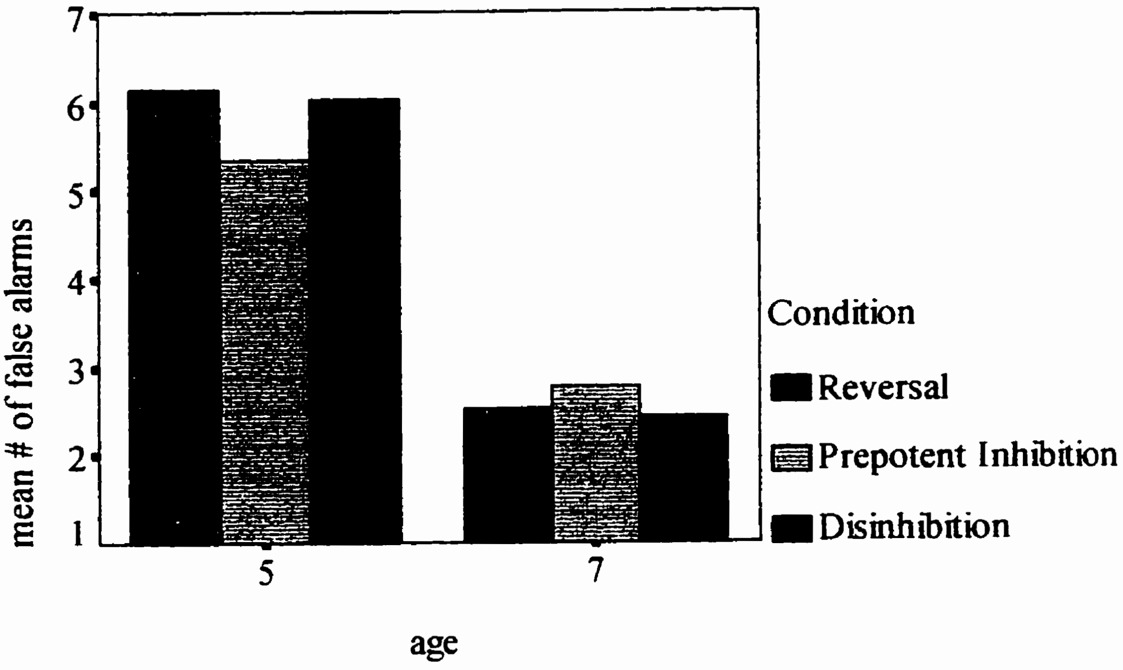


Figure 4. Mean false alarm rates of developmental group for each condition across phases.

Analyses of sex differences in false alarm rates collapsed across prime and probe phases revealed that the females (M = 2.56, SD = 2.20) made fewer false alarms than the males (M = 5.98, SD = 5.36), U (54) = 204.5, p = .01. Specifically, the females (M = 1.89, SD = 1.87) made fewer false alarms than the males (M = 6.31, SD = 5.71) during the Prepotent Inhibition condition, U (54) = 166.0, p = .001. Figure 5 presents the sex difference in false alarm rates collapsed across prime and probe phases for each condition. Further analyses indicated that the 5-year-old females (M = 2.87, SD = 2.24) made fewer false alarms than the 5-year-old males (M = 8.81, SD = 5.75), U (28) = 31.5, p = .002, but there was no difference between the false alarm rates of the 7-year-old females (M = 2.22, SD = 2.21) and the 7-year-old males (M = 2.92, SD = 2.64), U (26) = 63.0, p = .27. Figure 6 presents this sex difference in false alarm rates for the 5- and 7-year-old age groups.

There was no significant difference in mean false alarm rates between prime phases (M = 4.40, SD = 4.56) and probe phases (M = 4.13, SD = 4.61), T (54) = 1.79, p = .07, across conditions, for any condition considered separately, and for each age group. There was also no significant difference in mean false alarm rates (collapsed across phases) between any of the conditions.

To analyze shift effects within the probe phases, overall false alarm rates during the first half and second half of the probe phases were compared using nonparametric tests. The false alarm rates of the 7-year-olds were significantly greater during the first half (M = 1.41, SD = 1.63) than during the second half (M = 1.05, SD = 1.44) of the probe phases, T (26) = -2.43, p = .02. No difference in false alarm rates was found for

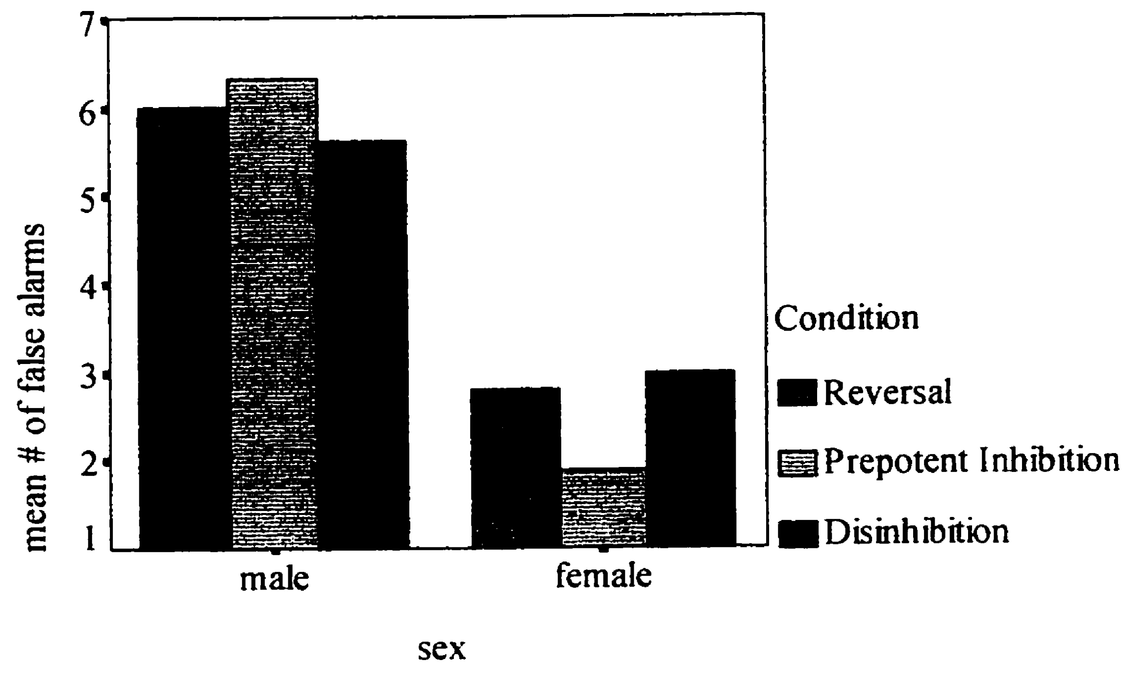


Figure 5. Sex differences in mean false alarm rates for each condition across phases.

Figure 6. Sex differences in mean false alarm rates for each age group.

the 5-year-olds during the first half (M = 3.02, SD = 2.77) and second half (M = 2.67, SD = 2.89) of the probe phases, T (28) = .65, p = .52 .

Across phases and conditions, the proportionate number of false alarms (M = 2.86, SD = 2.95) was significantly greater than the proportionate number of misses (M = .34, SD = .45) for both age groups combined, T (54) = -6.39, p = .001. This significant difference was also found within the 5-year-old group (false alarms: M = 3.91, SD = 3.51; misses: M = .51, SD = .56; T (28) = -4.62, p = .001), within the 7-year-old group (false alarms: M = 1.72, SD = 1.62; misses: M = .16, SD = .16; T (26) = -4.46, p = .001), within the group of 5- and 7-year-old males (false alarms: M = 4.00, SD = 3.59; misses: M = .39, SD = .59; T (27) = -4.54, p = .001), and within the group of 5- and 7-year-old females (false alarms: M = 1.71, SD = 1.48; misses: M = .29, SD = .25; T (27) = -4.54, p = .001).

Misses. None of the 6 distributions of mean number of misses approached normality, and thus nonparametric analyses were used. For all conditions and ages combined, fewer misses were made during the prime phases (M = .75, SD = 1.16) than during the probe phases (M = 1.30, SD = 1.69), T (54) = 3.88, p = .001. Overall, the 7-year-olds (M = .48, SD = .49) had fewer misses than the 5-year-olds (M = 1.54, SD = 1.71), U (54) = 167.5, p = .001. This significant age difference existed within the Reversal condition (7-year-old group: M = .48, SD = .64; 5-year-old group: M = 1.64, SD = 2.30; U (54) = 188.5, p = .001), the Prepotent Inhibition condition (7-year-old group: M = .38, SD = .52; 5-year-old group: M = 1.21, SD = 1.86; U (54) = 253.5, p = .04), and the Disinhibition condition (7-year-old group: M = .58, SD = .91; 5-year-old group: M =

1.75, SD = 2.08; U (54) = 253.5, p = .05). No significant sex differences existed in the number of misses, U (54) = 332.5, p = .58 across ages, conditions, or phases.

Correlations. Reaction time difference scores were used as measures of overall shift effects for each condition. RT difference scores consisted of the difference between the RTs of the probe and prime phases, and were positive because RTs during the probe phases were greater than RTs during the prime phases. These scores were used to calculate correlations among conditions, as well as between conditions and the verbal (TACL-R; Carrow-Woolfolk, 1985) and performance (subtests of the McCarthy Scales of Children's Abilities; McCarthy, 1972) measures.

Pearson product-moment correlations for both age groups combined revealed a significant correlation between mean RT difference scores of the Reversal and Disinhibition conditions, r (54) = .28, p = .04. Mean RT difference scores of the Reversal condition were not significantly correlated with those of the Prepotent Inhibition condition, r (54) = .24, p = .08; neither was there a significant correlation between mean RT difference scores of the Disinhibition and Prepotent Inhibition conditions, r (54) = .05, p = .73. The results of the same analysis on the RT difference scores of the 5-year-old children showed no significant correlations between conditions. For the 7-year-old children, however, the mean RT difference scores of the Reversal condition were significantly correlated with those of the Disinhibition condition, r (26) = .47, p = .02, *and* the Prepotent Inhibition condition, r (26) = .62, p = .001. There was no correlation between the 7-year-olds' mean RT difference scores of the Disinhibition and Prepotent Inhibition conditions, r (26) = .13, p = .54.

For both 5- and 7-year-olds combined, mean scores on the verbal measure (TACL-R; Carrow-Woolfolk, 1985) were significantly correlated with mean RT difference scores during the Prepotent Inhibition condition, $r\ (54) = -.30$, $p = .03$. Specifically, larger RT difference scores were associated with lower verbal scores. Mean scores on the performance measure, and scores on both the verbal and performance measures within each age group separately, were not significantly correlated with mean RT difference scores from any of the conditions.

Summary. In summary, the 7-year-olds responded more quickly and made fewer false alarms than the 5-year-olds. Specifically, there was no age difference in RTs during the prime phases, but the 7-year-olds were faster than the 5-year-olds during the probe phases. The 7-year-olds made fewer false alarms than the 5-year-olds during the Reversal condition. A sex difference in performance styles revealed that males responded more quickly than females. Males also made more false alarms than females at 5 years of age; however, no sex difference in false alarms existed at 7 years of age.

Across age and condition, reaction times during the prime phases were shorter than RTs during the probe phases; however, there was no difference in false alarm rates between the prime and probe phases. There were also no significant differences in false alarm rates between conditions. An inconclusive main effect of Condition from the analysis of RT data was examined further, and it was found that the RTs of both age groups were longer during the probe phases of both the Reversal and Disinhibition conditions than during the probe phase of Prepotent Inhibition condition. There was no difference in RTs between the probe phases of the Reversal and Disinhibition conditions.

Since this RT difference among conditions was not found during the prime phases, it seems that an interesting difference in performance difficulty among conditions may exist.

Fatigue effects indicated that, across age and condition, RTs were shorter during the first half than during the second half of the probe phases. More misses were made during the probe phase than during the prime phase. For all conditions, the 7-year-olds made more false alarms at the beginning versus the end of the probe phases, but this effect was not replicated with the 5-year-olds. The 5-year-olds responded to distractors more quickly than they responded to targets, and both age groups made proportionately more false alarms than misses. The 5-year-olds made more misses than the 7-year-olds.

For both age groups combined, there was a correlation between the RT difference scores of the Reversal and Disinhibition conditions. Mean RT difference scores of the Reversal and Prepotent Inhibition conditions were not correlated; neither were RT difference scores of the Prepotent Inhibition and Disinhibition conditions. No correlations were found for the 5-year-olds, and for the 7-year-olds, RT difference scores of the Reversal condition were correlated with those of both the Disinhibition *and* Prepotent Inhibition conditions. Scores of both age groups on the verbal measure were significantly correlated with RT difference scores of the Prepotent Inhibition condition.

Autistic data

Children with autism were matched to children in the developmental group according to baseline RTs during the prime phases of each task, gender, order of presentation of condition, and assignment of target colour. All statistical analyses that follow were conducted using these 2 groups as the between-subjects factor. An alpha level of .05 was used for all statistical tests unless otherwise specified.

Preliminary analyses. Preliminary comparisons were conducted to determine if there were differences between the groups on measures of verbal (TACL-R; Carrow-Woolfolk, 1985) or nonverbal (performance measure; McCarthy, 1972) abilities. Distributions of the verbal and performance measures approached normality, and thus parametric analyses were used. There was no significant difference between the autistic group (M = 84.60, SD = 23.92) and control group (M = 84.80, SD = 11.43) on the verbal measure, t (1, 18) = .02, p = .98. However, the autistic group (M = 28.30, SD = 3.06) had higher scores on the performance measure than the control group (M = 25.30, SD = 3.02), t (1, 18) = -2.21, p = .04. Therefore, the performance measure was entered as a covariate in the following MANOVA analysis.

Reaction times. Four of the 6 distributions of mean RTs approached normality. Due to the robustness of analysis of variance when all distributions are not normal, parametric analyses were used. Mean RTs were analyzed in a 2 x 3 x 2 (Group x Condition x Phase) repeated-measures MANOVA, with scores on the performance measure entered as a covariate. Group (autistic or control) was the between-subjects factor, while Condition (Reversal, Prepotent Inhibition, Disinhibition) and Phase (prime, probe) were the within-subjects factors. The MANOVA revealed only one significant effect, the main effect for Phase, F (1, 17) = 25.73, p = .001. Neither the main effect for Group, F (1, 16) = .11, p = .75, nor any interactions with Group even approached significance. Overall, mean RTs during the prime phases (M = 434.09, SD = 68.69) were significantly shorter than mean RTs during the probe phases (M = 491.07, SD = 86.14). The pattern of responding for both groups across conditions was similar to that found in the developmental study. To demonstrate the similarity between the autistic group and the developmental data, Figure 3 presents mean RTs across both phases of each condition for the autistic group.

To analyze fatigue effects, overall mean RTs for the first and second half of the probe phases were entered in a 2 x 3 x 2 (Group x Condition x Block) repeated-measures MANOVA. Group (autistic or normal) was the between-subjects factor, while Condition (Reversal, Prepotent Inhibition, Disinhibition) and Block (first 30 trials or last 30 trials of the probe phases) were the within-subjects factors. The MANOVA revealed a significant 2-way interaction for Condition x Block, F (2, 34) = 5.03, p = .01, and a significant 3-way interaction for Group x Condition x Block, F (2, 34) = 3.17, p = .05. The autistic group's RTs during the first half (M = 456.23, SD = 174.02) of the probe phase were significantly faster than RTs during the last half (M = 544.03, SD = 144.36) of the probe phase for the Reversal condition, t (9) = -2.44, p = .04. This difference in RTs across the probe phase was not found for any other condition, nor for the control group in any condition.

The overall RTs of false alarms made by the autistic group (M = 440.84, SD = 127.05) were not significantly shorter than the RTs of their hits (M = 450.90, SD = 89.79), T (7) = -.17, p = .87. This lack of difference in RTs between false alarms and hits existed for the control group as well.

False alarm error rates. Since 4 of the 6 distributions of mean false alarm rates did not approach normality, nonparametric analyses were used. An alpha level of .01 was used for these analyses, as calculated by the Bonferroni correction for Type 1 error rate. None of the tests revealed statistically significant results. In particular, there was no significant difference in mean false alarm rates between the autistic group and the control group, *U* (19) = 42.5, *p* = .84. A nonsignificant difference in mean false alarm rates between groups existed within the Reversal condition (autistic group: *M* = 3.60, *SD* = 3.01; control group: *M* = 6.70, *SD* = 7.33; *U* (20) = 41.5, *p* = .52), the Prepotent Inhibition condition (autistic group: *M* = 3.35, *SD* = 2.00; control group: *M* = 6.20, *SD* = 5.08; *U* (20) = 34.5, *p* = .24), and the Disinhibition condition (autistic group: *M* = 8.61, *SD* = 6.57; control group: *M* = 6.25, *SD* = 6.61; *U* (19) = 33.0, *p* = .33).

Analyses of shift effects revealed that the control group made significantly more false alarms during the first half of the probe phases (*M* = 3.63, *SD* = 3.20) than during the second half of the probe phases (*M* = 2.27, SD = 2.17), *T* (10) = 2.31, *p* = .02. However, for the autistic group, there was no significant difference in false alarm rates during the first half of the probe phases (*M* = 2.52, *SD* = 1.75) and the second half of the probe phases (*M* = 2.07, SD = 1.73), *T* (9) = 1.47, *p* = .14.

Across phases and conditions, the proportionate number of false alarms (*M* = 3.45, *SD* = 2.29) was significantly greater than the proportionate number of misses (*M* = .30, *SD* = .31) for the autistic group, *T* (9) = -2.67, *p* = .01. A significant difference between the proportionate number of false alarms and misses was also found for the control group, *T* (10) = -2.80, *p* = .01.

Misses. None of the 6 distributions of mean number of misses approached normality, and thus nonparametric analyses were used. None of the tests revealed statistically significant results. There was no significant group difference in mean number of misses between the autistic group and the control group, U (19) = 39.5, p = .65. There was also no significant difference across conditions in the mean number of misses between the prime and probe phases, T (19) = 1.07, p = .29.

Correlations. Reaction time difference scores were used as measures of overall shift effects for each condition in the same way as for the developmental data. These scores were used to calculate correlations among conditions, as well as between conditions and the verbal and performance measures.

Pearson product-moment correlations for both the autistic and control groups combined revealed that mean RT difference scores of the Reversal condition were significantly correlated with mean RT difference scores of the Prepotent Inhibition condition, r (20) = .55, p = .01. The correlation between mean RT difference scores of the Reversal and Disinhibition conditions was nonsignificant, r (19) = -.37, p = .12, as was the correlation between the mean RT difference scores of the Prepotent Inhibition and Disinhibition conditions, r (19) = -.08, p = .75. The results of the same analysis on the RT difference scores of the autistic group revealed no significant correlations between conditions. For the control group, the correlation between mean RT difference scores of the Reversal and Prepotent Inhibition conditions approached significance, r (10) = .60, p = .07. For both groups considered together, and for each group separately, mean scores on the verbal and performance measures were not significantly correlated with mean RT difference scores from any of the conditions.

Control group matched on performance scores. To explore the data further, the autistic group was also matched to participants in the developmental group according to their raw scores on the performance measure (subtests of the McCarthy Scales of Children's Abilities; McCarthy, 1972) and gender. Performance scores are most often used to match clinical and control groups during reaction time studies (Ciesielski et al., 1990; Hughes & Russell, 1993). All analyses were repeated using this new control group; only the discrepant results are reported. Notably, there were still no group differences in RT or error data using this new control group. Analysis of the RTs in a 2 x 3 x 2 repeated-measures MANOVA revealed an additional significant main effect of Condition, F (2, 34) = 3.81, p = .03. Significant differences in mean RTs between conditions paralleled the results of the developmental group alone. Mean RTs during the Reversal condition (M = 486.46, SD = 124.85) were significantly longer than RTs during the Prepotent Inhibition condition, t (20) = 2.56, p = .02, but not longer than RTs during the Disinhibition condition, t (19) = -.27, p =.79. Mean RTs during the Disinhibition condition (M = 486.37, SD = 128.04) were also significantly longer than RTs during the Prepotent Inhibition condition (M = 440.78, SD = 92.11), t (19) = 2.19, p = .04.

Repeating the correlations revealed no significant correlations between the RT difference scores of any of the conditions. For both the autistic and control groups combined, there was a significant negative correlation between performance scores and the mean RT difference scores of the Disinhibition condition, r (19) = -.63, p = .004, but no significant correlations were found between performance scores and mean RT difference scores from the other two conditions. High performance abilities were thus associated with less difficulty during the Disinhibition condition.

Summary. In summary, there were no differences between groups or conditions for RTs or false alarm rates. For both the autistic and control groups matched on baseline RTs or the performance measure (McCarthy, 1972), RTs during the prime phases were shorter than RTs during the probe phases, but there was no phase difference in false alarm rates across conditions. Differences in RTs among conditions replicated the developmental data when the control group was matched to the autistic group according to scores on the performance measure.

For the autistic group, fatigue effects were found during the Reversal condition, where RTs were shorter during the first half than during the second half of the probe phase. For all conditions, the control group made more false alarms at the beginning versus the end of the probe phases, but this effect was not replicated with the autistic group. Both groups made proportionately more false alarms than misses.

For both age groups combined, there was a correlation between the RT difference scores of the Reversal and Prepotent Inhibition conditions. Mean RT difference scores of the Reversal and Disinhibition conditions were not correlated; neither were RT difference scores of the Prepotent Inhibition and Disinhibition conditions. No correlations were found for the autistic group alone, and for the control group, RT difference scores of the Reversal condition tended to be correlated with those of the Prepotent Inhibition condition. When the autistic group was matched to a control group according to performance scores as well as baseline response times, the performance scores of both groups were negatively correlated with RT difference scores of the Disinhibition condition, indicating an association between high performance skills and less difficulty during the Disinhibition condition.

Discussion

This study was designed to explore the role of inhibition in visual selective attention; in particular, how inhibition develops in 5- and 7-year-old typically developing children and whether inhibition and/or its development is dysfunctional in 12-year-old children with autism. It was expected that inhibition would develop with age and may be enhanced in individuals with autism (Bryson, 1995).

The Go-NoGo visual selective attention task used in this study required participants to flexibly regulate their attention toward one location and was designed to measure specific components of inhibition. The main Reversal condition, identical to the prepotent inhibition condition in Ozonoff et al.'s (1994) study, was modified from the visual focus attention task designed by Ciesielski et al. (1990). During the prime (baseline) phase, two visual stimuli (target and distractor) were presented one-at-a-time on a computer monitor, and participants were required to respond manually every time a target stimulus was detected. The roles of the target and distractor stimuli were reversed during the probe (test) phase of the Reversal condition, requiring participants to ignore the previous target (prepotent inhibition) and respond to the previous distractor (disinhibition).

This study examined whether tasks such as the above Reversal condition confound two abilities that may exist as independent components of inhibition: the ability to inhibit a prepotent response, and the ability to disinhibit, or overcome built-up inhibition. Ozonoff et al.'s (1994) report that individuals with autism experienced difficulty on an inhibition task identical to the present Reversal condition begs the question of whether prepotent inhibition and/or disinhibition contribute to or account for this effect. Two additional conditions, the Prepotent Inhibition and Disinhibition conditions, were thus designed as separate measures of these abilities (see Figure 1). During the probe phase of the Prepotent Inhibition condition, participants were required to ignore the previous target (implement inhibition) and respond to a new target. The probe phase of the Disinhibition condition required participants to respond to the previous distractor (overcome inhibition) and ignore a new distractor.

The role of inhibition in the development of normal 5- and 7-year-old children will be considered first, followed by an exploration of inhibition in 12-year-old males with autism. Reaction time (RT) data to the target stimuli and error data (false alarm rates and misses) were examined as measures of performance.

The development of inhibition

Analyses of the RT and error rate data of the 5- and 7-year-old children resulted in two major findings, as well as a third post-hoc finding. Both age groups experienced difficulty shifting attention, as indicated by longer RTs during the probe phases than during the prime phases of each condition. Secondly, there was no age difference during the prime phases that measured selective attention abilities. However, when required to shift attention during the probe phases, the 7-year-old children responded more quickly to the target stimuli and made fewer errors, in the form of false alarms and misses, than the 5-year-old children. Lastly, some correlational and post-hoc evidence suggests the possibility that disinhibition and prepotent inhibition may exist as separate aspects of selective attention, and that overcoming inhibition toward a distractor stimulus may be just as difficult (or even more so) than the inhibition of a response.

Longer RTs during the probe phases than during the prime phases for both the 5- and 7-year-old children provides evidence for an attentional shift effect. An increase in RT latencies implies that the children found the test phases more difficult than the baseline selective attention phases, requiring more time to organize their responses. This suggests that the shift from the prime phases to the probe phases of each condition was validly measured, and most likely required components of selective attentional control and/or inhibition. However, an increase in RTs during the probe phases was not accompanied by an increase in error rate, which would also have indicated shift difficulty. A false alarm was measured as an erroneous response to the distractor stimulus, and is best described as an inability to inhibit a prepotent response. Since the children took longer to respond during the probe phases while retaining their accuracy rates, the task may have not been difficult enough to cause elevated error rates.

As predicted, when required to shift attention, the 7-year-old children were better inhibitors, responding more quickly to the target stimuli and making fewer errors (false alarms and misses) than the 5-year-old children. Many reaction time studies have shown that, due to general maturation, RTs become shorter as age increases to adulthood. The 7-year-olds missed fewer targets than the 5-year-olds; this evidence for an age-related development of the ability to sustain focused attention has been reported in other studies as well (Levy, 1980; McKay, Halperin, Schwartz, & Sharma, 1994). The tendency to perseverate, as measured by elevated false alarm rates, has also been shown to decrease with age (Passler, Isaac, & Hynd, 1985; Zelazo et al., 1996). Specifically, the 7-year-old children made fewer false alarms than the 5-year-old children during the Reversal condition (see Figure 4). The older children were better at withholding their responses, presumably due to more mature inhibitory mechanisms. In addition, unlike the 7-year-old children, the 5-year-old children made fast, impulsive errors that could not be inhibited. Quite possibly the 7-year-old children were not as impulsive as the 5-year-old children, due to increased control and greater organization of their responses.

The 7-year-old children responded significantly more quickly to the target stimuli than the 5-year-old children only during the probe phases of each condition; RTs during the prime phases were similar between age groups (see Figure 2). This negative finding for RTs during the prime (baseline) phases implies that the 5-year-olds were as capable as the 7-year-olds at selectively attending to their environment. Other studies have documented similar developmental trends in selective attention. McKay et al. (1994) studied sustained attention, selective attention, and response organization between the ages of 7 and 11 (as well as during adulthood). During a Go-NoGo selective attention task, participants were required to respond to a specific colour when it appeared in the centre of the computer display, and ignore other interspersed colours while the number of distractors in the periphery was varied. Interestingly, no age effect was found using this paradigm, a result that was attributed to the possibility that selective attention reaches adult levels before 7 years of age. In comparison with the older age groups, the 7-year-old participants in the study by McKay et al. did experience difficulty organizing responses during tasks that involved competing and noncompeting motor responses. It may be that age differences with young children appear only when prepotent inhibition and/or disinhibition are required (during shift tasks), because responses need to be organized in cognitive *and* motor domains. During selective attention, the main requirement is attentional focus on the target, an ability that may develop very early in life. Past literature has found that the ability to selectively attend to the environment remains relatively constant from childhood to adulthood (Ridderinkhof & van der Molen,1995; Tipper et al., 1989).

Previous literature has documented that inhibition develops with age (Day & Stone, 1980; Lane & Pearson, 1982; Pick et al., 1972; Tipper et al., 1989). Individual studies have shown the development of inhibitory control between the ages of 5 and 7 (Passler et al., 1985; Ridderinkhof & van der Molen, 1995; Smith et al., 1975). Recently, van der Meere, Gunning, and Stemerdink (1996) found a developmental increase in the ability to flexibly plan and execute a response, as well as in the ability to shift to an alternative response. Seven-year-old children should be able to deal more effectively than 5-year-old children with various situations that demand different aspects of selective attention and/or inhibition. Between 5 and 7 years of age, inhibition may develop to such a degree that inhibiting responses becomes easier *and* overcoming this inhibition becomes easier as well; that is, the ability to successfully and adaptively maintain inhibitory control has developed. Past literature has also shown that a difference may exist in the attention strategies of 5- and 7-year-old children. Smith et al. (1975) found that 5-year-old children employed a divided attention strategy during a cross-modal selective attention task, whereas 7-year-old children used a focusing strategy. Therefore the 5-year-old children performed best by using a nonselective strategy, but the overall greater performance of the 7-year-old children was attributed to their increased ability to selectively attend to their environment and ignore irrelevant stimuli (Smith et al., 1975).

There was an unanticipated sex difference in the RTs and false alarm rates of the 5- and 7-year-old children that highlights a difference in the response styles of boys and girls. The boys responded more quickly and made more false alarms than the girls. However, only 5-year-old boys made more false alarms than 5-year-old girls; the sex difference was nonsignificant at 7 years of age. It seems that the 5-year-old boys risked errors in order to respond quickly to stimuli presented on a computer, whereas the 5-year-old girls tended to respond cautiously, with less speed but greater accuracy. Thus the 5-year-old boys may view speed as the most important factor in the speed-accuracy equation, while the 5-year-old girls would rather be careful and accurate than fast and inaccurate in their responses. At 7 years of age, the boys still responded more quickly than the girls, but no longer made more errors than the girls. It could be that a tendency exists for boys to respond more quickly than girls, and that at age 5, this tendency results in a greater error rate because of immature inhibitory control. By age 7, the tendency of boys to respond more quickly than girls does not result in greater errors than girls, perhaps due to the development of the ability to inhibit responses. This makes sense particularly because an overall sex difference in false alarm rates was only found during the Prepotent Inhibition condition (see Figure 5), when the active inhibition of a response was required.

Since a shift of attention was required as each probe phase was introduced, it was expected that RTs and/or error rates during the probe phases might be greater at the beginning of the probe phases, when inhibition was initially required. However, RTs tended to increase across the duration of the probe phases, a finding that may be explained by fatigue effects. There was a tendency for false alarm rates to decrease across probe phases, but only during the Reversal and Prepotent Inhibition conditions. Perseveration occurred immediately following the inhibition of a response and diminished over time, providing evidence for a rapid shift effect due to the change in task demands. During the probe phase of the Disinhibition condition, however, when prepotent inhibition was not required, an opposite performance trend was revealed; there were (nonsignificantly) fewer false alarms made at the beginning (versus the end) of the probe phase. The duration and frequency of perseveration of a response most likely depends on the saliency of the prepotent response. Responding to a target over an increased number of trials during the prime phase may make this response more difficult to inhibit. In this study, responding to a target 20 times over 60 trials did cause false alarms when prepotent inhibition was required, but this perseveration declined rapidly over the next 60 trials.

Longer RTs at the end (versus the beginning) of the probe phases, as well as more missed targets during the probe phases than the prime phases, both suggest the possibility that the attention spans of the 5- and 7-year-old children may have waned by the end of the task. Although both groups made proportionately more false alarms than misses (indicating focused attention), it is possible that participants became fatigued or less motivated to respond quickly and accurately as they completed the task. Many of the 5- and 7-year-old children related to the experimenter that they found these 'colour games' quite dull and easy compared to their previous experiences with computer games. The behavior of some children indicated that they were bored and at times had difficulty tolerating the games until completion. Preliminary data collection included a 3-year-old age group, but the task proved impossible for children this young. The task was even too difficult for most 4 year olds, because at this age there was a general inability, given the parameters of the task, to inhibit responses and follow rules correctly. It seems that by age 5, the ability to sustain attention and/or selectively attend to visual stimuli has developed enough to allow for successful performance.

Some support for separate inhibitory mechanisms is provided by correlations among RT difference scores for each condition. RT difference scores, the difference between the prime and probe phases of each condition, were considered appropriate measures of shifting difficulty. For both age groups, RT difference scores for the Reversal condition were significantly correlated with RT difference scores for the Disinhibition condition ($\underline{r} = .28$), but not with the scores for the Prepotent Inhibition condition. Thus disinhibition may well account for more of the variance within the Reversal condition than the inhibition of a prepotent response. This correlation, however, was not found with the RT difference scores of the 5-year-old children alone. It seems that the correlation across age groups was mainly influenced by the RT difference scores of the 7-year-old children. The 7-year-olds' RT difference scores for the Reversal condition were significantly correlated with their scores for both the Disinhibition ($\underline{r}$ =

.47) and the Prepotent Inhibition (r = .62) conditions. Thus at 7 years of age, both inhibition of a prepotent response *and* disinhibition accounted for the variance within the Reversal condition. This finding implies that, although undetected by the overall RT analysis, the Reversal condition may have measured both disinhibition and prepotent inhibition. Note further that the RT difference scores of the Prepotent Inhibition and Disinhibition conditions were not significantly correlated; this suggests that the tests employed here are measuring different aspects of inhibition.

The RT difference scores from the Prepotent Inhibition condition were significantly negatively correlated with verbal scores on the TACL-R (r = -.30; Carrow-Woolfolk, 1985). Higher verbal scores were associated with less difficulty inhibiting a prepotent response. The association between prepotent inhibition and language underscores the regulatory role of speech in shaping behavior. As Luria (1961) hypothesized and examined, young children (under 3 years of age) rely on external speech (from adults) to regulate their behavior; by the age of 4, external speech is internalized and internal speech now begins to guide behavior. Luria found that external speech could not motivate children to inhibit behavior, but as children's language abilities developed, so did their ability to inhibit behavior and shift to a new task.

It was hoped that this study would discover whether the Prepotent Inhibition and Disinhibition conditions measure separate components of inhibition. To further explore performance differences among conditions, additional post-hoc tests were conducted following an inconclusive main effect for Condition averaged across phases. Given the exploratory nature of this research and the preliminary use of the Prepotent Inhibition and

Disinhibition conditions in the Go-NoGo paradigm, it was believed that this analysis was warranted. The post-hoc tests revealed a significant RT difference among conditions during the probe phases, accompanied by no RT difference among conditions during the prime phases. This is consistent with an interpretation of differential difficulty among conditions, since the probe phases alone measured shifts in attention. Mean RTs of both the 5- and 7-year-old children were greater during the probe phases of the Reversal and Disinhibition conditions than during the probe phase of the Prepotent Inhibition condition (see Figure 3). The probe-phase difference between the response latencies of the Prepotent Inhibition and Disinhibition conditions suggests the possibility that these tests measured different aspects of selective attention.

It was predicted that the Reversal condition would be the most difficult condition, since it required children to concurrently fulfill the separate task demands of both the Prepotent Inhibition and Disinhibition conditions. Increased latencies in RTs during the probe phase of the Reversal condition as opposed to the Prepotent Inhibition condition indicate that the Reversal condition may indeed have been more difficult than the Prepotent Inhibition condition. It could be that simultaneously inhibiting a response *and* overcoming inhibition toward a distractor stimulus demanded more resources in the mental and/or motor organization of a response than did simply inhibiting a response. Overcoming inhibition toward a distractor, the sole task of the Disinhibition condition, was also found to be more difficult (based on probe-phase RTs) than inhibiting a prepotent response. However, RT latencies during the probe phases were similar during the Reversal and Disinhibition conditions. This raises the possibility that the inhibition of a response and the disinhibition of a distractor at the same time may not considered more difficult than the disinhibition a distractor alone.

The post-hoc findings highlight a difference in performance difficulty among conditions that needs to be explored further. Future research may possibly find that disinhibition exists as a separate component of inhibition. This study provides tentative evidence that the ability to overcome built-up inhibition toward a distractor stimulus over time may be more, or at least as, difficult than inhibiting a prepotent response. The potential role of disinhibition has been overlooked in standard Go-NoGo or negative priming studies that only analyze prepotent inhibition during shifts of attention that involve reversing the target and distractor stimuli (see, for example, Ozonoff et al., 1994). It may be that Reversal conditions, such as that used in the present study, incorporate both prepotent inhibition and disinhibition, with disinhibition possibly accounting for most of the difficulty in shifting attention. Additional research, with greater statistical power and/or a more sensitive measure, may be able to more clearly differentiate between the two possible components of inhibition.

Inhibition in autism

The children with autism were matched with children from the developmental sample based on their mean RTs during the selective attention task (prime phases), gender, randomized assignment of target colour, and randomized order of presentation of conditions (see Table 2). Most prominently, there were no significant differences in RTs or error rates between the autistic and control groups. Thus the only finding of significance was an increase in RTs across phases, indicating that shifting attention was more difficult than responding selectively during the baseline phases.

It appears that the autistic and control groups experienced no specific difficulties with any of the task demands in this study, other than an overall increase in RTs when required to shift attention. The children with autism were able to successfully focus their visual attention toward one location as well as the control group. Recall that the performance of autistic individuals on negative priming tasks is comparable to that of normal control groups (Bryson, 1995; Hill, in prep.), reinforcing the present results and the claim by Ciesielski et al. (1990) that individuals with autism perform as well as CA- and MA-matched control groups during a visual selective attention task. However, robust past evidence demonstrating that individuals with autism tend to perseverate (Bryson, 1995; Casey et al., 1993; Ciesielski et al., 1990; Hill, in prep; Ozonoff et al., 1994) was not replicated in the present study.

It was not expected that the children with autism would be indistinguishable from the control group. To further explore this possibility, the autistic group was also matched to children from the developmental sample according to their raw scores on the performance measure (McCarthy, 1972), and gender. Performance scores are most often used to match clinical and control groups during similar (nonverbal) RT studies (Ciesielski et al., 1990; Hughes & Russell, 1993). Notably, there were still no group differences in RT or error data using this new control group. Overall, significant differences in RTs among conditions paralleled the results found for the developmental data. Thus matching on performance scores made overall trends appear more identical to the norm. As well, performance scores were significantly negatively correlated with RT difference scores of the Disinhibition condition (r = -.63), indicating that those children with high performance scores experienced less difficulty overcoming inhibition toward a distractor, or that an ability to disinhibit was associated with high performance ability.

A correlation between performance scores and RT difference scores of the Disinhibition condition alone also provides evidence that disinhibition may exist as a separate component of inhibition (recall that for the developmental data, verbal scores on the TACL-R and RT difference scores of the Prepotent Inhibition condition were significantly correlated). Consistent with this, and identical to the correlations found for the developmental data, is the finding that the RT difference scores of the Prepotent Inhibition and Disinhibition conditions were not significantly correlated.

The participants with autism in Ozonoff et al.'s (1994) Go-NoGo study experienced elevated RTs during a Reversal condition (referred to as a prepotent inhibition condition) compared to MA-matched normal control children. This evidence suggests that inhibition toward one location may be impaired in autism. The present Reversal condition was almost identical to Ozonoff et al.'s prepotent inhibition condition, and the participants in the present study (M = 11.6 years, SD = 1.38) were the same age as the participants in Ozonoff et al.'s study (M = 12.4 years, SD = 2.47). Two possibilities could account for the fact that Ozonoff et al.'s findings were not replicated in the present study. First, in Ozonoff et al.'s Reversal task, participants were required to shift between forms (circle or square), whereas the present task involved a shift within a single form (squares of different colours). Consistent with Rincover and Ducharme's

(1987) hypothesis of overselective attention, shifting attention between categories may be more challenging for individuals with autism than shifting attention within a category. Secondly, although the stimulus duration was quite long (250 ms) during the Ozonoff et al. task, the interstimulus intervals (ISIs) were 1000 ms and participants were required to respond to 30 blocks of 20 trials each. Most likely, this made their task more challenging than the present task, which used longer ISIs (1500 - 2500 ms) and fewer trials (2 blocks of 60 trials each). Shorter ISIs would no doubt be associated with greater perseveration due to fast, uncontrolled responding, and an increased number of trials should make the task more reliable; both should emphasize possible group differences.

Further evidence from the present study suggests that the children with autism were not challenged by the task. The RTs of false alarm rates were not significantly shorter than the RTs of hits, indicating that false alarms were not fast, impulsive errors due to difficulties shifting attention. However, the children with autism did tend to make more false alarms during the first half than during the second half of the probe phase of the Reversal condition, revealing a slight difficulty inhibiting responses during the condition with the most task demands. The autistic group was focused and motivated to attend to the tasks, as overall there were proportionately more recorded errors than misses. As well, recall that there was an overall increase in RT latencies during the test phases. Thus participants did experience a general difficulty in response organization when required to shift attention, but no more or less so than the control group.

The neurophysiological study by Ciesielski et al. (1990) demonstrated that measures of performance may sometimes be inadequate when analyzing the behavior of clinical populations. Even though a group of adults with autism performed as well as CA- and MA-matched control groups on a visual selective attention task, abnormal neurological activity was recorded for this group. Specifically, Ciesielski et al. found that the participants with autism did not show negative difference waves in their ERP-recordings--activity in the frontal cortex that is believed to be responsible for stimulus selection. Ciesielski et al. concluded that individuals with autism may be able to successfully employ their focused and selective attention in various circumstances, but that they may use different selective attention mechanisms. As these authors suggest, more difficult tasks (such as shifting attention across modalities) may weaken performance because compensatory mechanisms cannot be employed under greater demands. If individuals with autism are neurophysiologically different from the normal population and/or if they employ unique selective attention mechanisms, then the present study may have demonstrated the ability of a sample of autistic children to appear typical through the use of autism-specific mechanisms during selection, inhibition, and disinhibition.

Another possibility is that individuals with autism do not experience any difficulty shifting attention during a *non-spatial* Go-NoGo task presented in the visual modality. Considering that the overall pattern of responding within conditions paralleled the developmental data, and the fact that an overall shift effect was found for all conditions, it may be that selective attention and inhibition in autism is not deviant for this particular task. It bears emphasizing that, unlike the present task, virtually all traditional Go-NoGo tasks involve a spatial element. Numerous studies have found that individuals with autism experience difficulty shifting and/or disengaging attention across space within one modality (Casey et al., 1993; Rincover & Ducharme, 1987; Wainwright-Sharp & Bryson, 1993; Wainwright & Bryson, 1996) and across modalities (Casey et al., 1993; Ciesielski et al., 1990; Courchesne et al., 1994). When a task requires a shift from one location to another within the visual modality, individuals with autism take longer to respond and make more errors than matched control groups. As postulated by Casey et al. (1993), visual-spatial attention may be selectively impaired in autism. The results from the present study raise the interesting possibility that the ability to shift and/or disengage across stimuli presented at one location is not impaired in autism, despite evidence of an impaired ability to shift and/or disengage across space. Due to the well-established overfocused attention and 'tunnel vision' of individuals with autism (Casey et al., 1993; Lovaas et al., 1971; Rincover & Ducharme, 1987), there may exist an intact ability to shift and/or disengage within a particular focused location. In autism, built-up inhibition toward distractors in the periphery may be greater than inhibition associated with focused attention. Therefore the finding of enhanced inhibition in autism may be specific to tasks requiring spatial shifts, as suggested by Bryson (1995).

General discussion

Past literature has found that selective attention develops early in life (McKay et al., 1994; Ridderinkhof & van der Molen, 1995), and results from the present study support this claim. No performance differences during the baseline selective attention task were found between the 5- and 7-year-old children. Responding during the selective attention task was also comparable between the autistic and control groups, consistent with other research that has documented intact selective attention in autism (Bryson, 1995; Ciesielski et al., 1990; Hill, in prep., Ozonoff et al., 1994).

The 7-year-old children responded more quickly and made fewer errors than the 5-year-old children during the probe phases, suggesting that inhibition develops between 5 and 7 years of age. This evidence is consistent with other studies that have observed developmental changes in inhibition (versus selection) between the ages of 5 and 7 (Passler et al., 1985; Ridderinkhof & van der Molen, 1995; Smith et al., 1975). In the present task, as in real life, the development of inhibitory control allows 7-year-old children to respond more flexibly and effectively than 5-year-old children when presented with varying situations involving prepotent inhibition and/or disinhibition.

Overall, the performance of the autistic group did not differ from that of the control group. The children with autism did not display an exaggerated tendency to perseverate or a greater ability to inhibit responses, as expected from the hypothesis that individuals with autism exhibit enhanced inhibition (Bryson, 1995). Due to the fact that elevated false alarm rates were not found for the children with autism, and perseveration in autism is well-documented (Bryson, 1995; Casey et al., 1993; Ciesielski et al., 1990; Hill, in prep; Ozonoff et al., 1994), it may be that the task was not challenging for these children. Evidence from Ozonoff et al.'s (1994) study, which used a Reversal task with more difficult parameters, suggests that children with autism may experience difficulty with prepotent inhibition and/or disinhibition. The present Go-NoGo paradigm could be made more difficult by decreasing the ISIs and/or duration of stimuli presentations, and an increased number of trials could increase reliability.

The null results for the children with autism require further investigation. The small sample size and low statistical power hinders the ability to predict why no difference was found between the children with autism and control groups matched on baseline RT or performance scores. It is speculated, however, that focused inhibition in autism may be comparable to inhibition in normal development, but that the ability to inhibit across space may still be impaired (Bryson, 1995; Casey et al., 1993). Another alternative is that inherent neurophysiological differences in autism and/or unique inhibitory mechanisms may be masked by typical performances (Ciesielski et al., 1990).

Correlational evidence from both the developmental and clinical data suggest that the main Reversal condition may have measured two separate inhibitory components (prepotent inhibition and disinhibition). Exploratory post-hoc tests revealed that the developmental group found the probe phase of the Reversal condition more difficult than the inhibition of a prepotent response. As well, overcoming built-up inhibition toward a distractor took longer, and was more difficult than, inhibiting a response. This finding, coupled with the correlational evidence, suggests the intriguing possibility that disinhibition may exist as a separate component of inhibition. Future studies that refine the paradigm used in this study may be able to provide stronger evidence for the independent existence of disinhibition.

In summary, this study provided evidence that visual selective attention abilities remain constant between 5 and 7 years of age, but that inhibition develops at this time.

No evidence was found for enhanced or atypical inhibition in 12-year-old males with autism. Although participants did not find the separate conditions of the Go-NoGo task differentially difficult, exploratory post-hoc analyses are consistent with the possibility that prepotent inhibition and disinhibition may exist as separate components of inhibition. This question remains outstanding, and needs to be explored further. Future research will help to illuminate the possibility of independent developmental trends for prepotent inhibition and disinhibition, and establish the precise nature of the inhibitory difficulties previously documented in autism. Even the most basic, simple tasks we encounter daily require us to employ inhibition, and uncovering separate mechanisms of inhibition may help to explain why and when inhibitory problems occur throughout the life span and within clinical populations.

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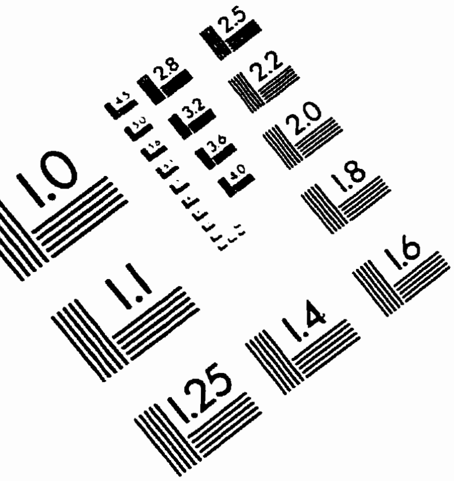
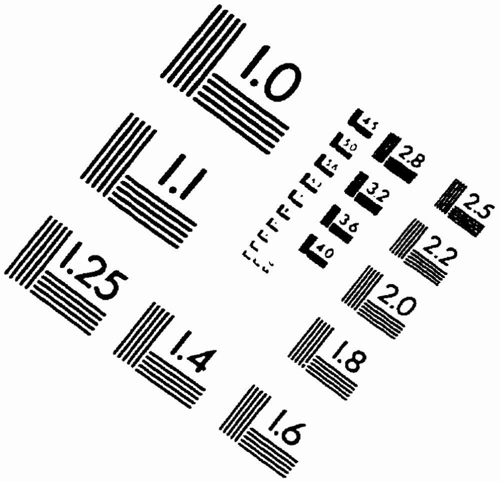
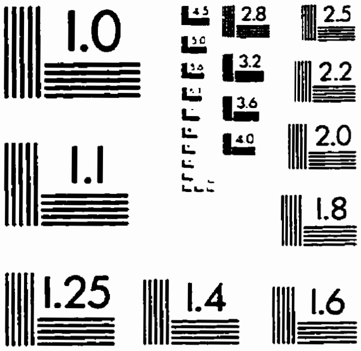
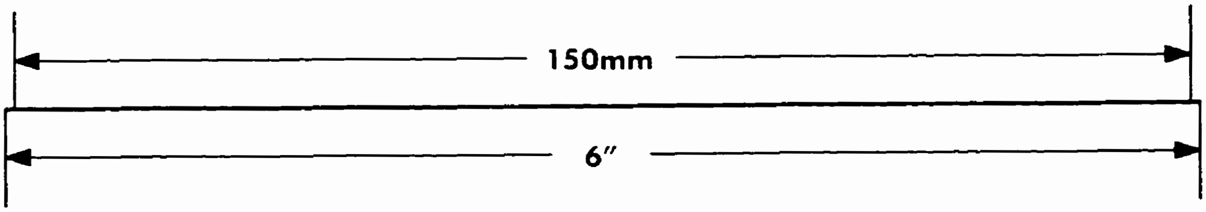
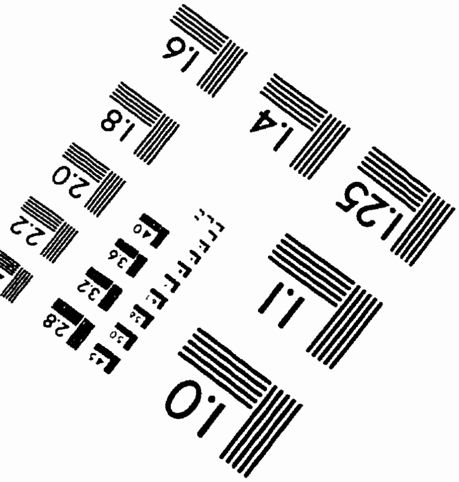
IMAGE EVALUATION TEST TARGET (QA-3)

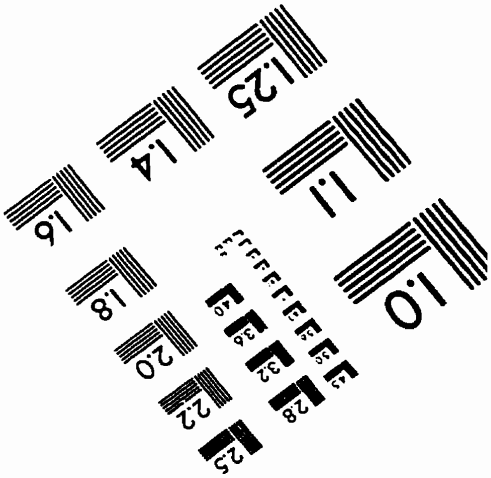












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