

## Development of Mental Attention in Gifted and Mainstream Children: The Role of Mental Capacity, Inhibition, and Speed of Processing

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The study examined performance of 6- to 11-year-old children, from gifted and mainstream academic programs, on measures of mental-attentional capacity, cognitive inhibition, and speed of processing. In comparison with mainstream peers, gifted children scored higher on measures of mental-attentional capacity, responded more quickly on speeded tasks of varying complexity, and were better able to resist interference in tasks requiring effortful inhibition. There was no group difference on a task requiring automatic inhibition. Comparisons between older and younger children yielded similar results. Correlations between inhibition tasks suggest that inhibition is multidimensional in nature, and its application may be affected by task demands. Measures of efficiency of inhibition and speed of processing did not explain age or group differences on a complex intellectual measure of mental-attentional capacity.

Three factors that have been advanced to account for developmental and individual differences in cognitive performance are capacity for activating relevant information, efficiency in inhibiting irrelevant information, and speed of processing. The present study investigated these three factors in samples of younger and older children enrolled in either gifted or mainstream (i.e., nongifted) academic programs to determine whether academically gifted children are advanced in these basic cognitive processes. Although a good deal of research has been conducted on the relationship between speed of processing and intelligence, relatively little research exists on activation and inhibition processes in intellectually gifted children.

### *Mental-Attentional Capacity*

Pascual-Leone (1987) has proposed a model of mental attention that includes both activation and inhibition processes. The activation component

(called *M* capacity) is seen as a limited capacity to boost activation of schemes relevant for task performance. *M* capacity is measured in terms of the maximal number of mental schemes—not directly activated by the input—that a person can actively keep in mind (i.e., within mental attention) at any one time (Pascual-Leone, 1970). *M* capacity is related to the notion of working memory but is not the same as working memory. We can define working memory as all the schemes in a person's repertoire that momentarily are sufficiently activated to affect the ongoing mental processing. *M* capacity would be one source of activation for these schemes, but because additional sources of activation exist (e.g., affect, overlearning, field factors), the size of working memory is likely to be greater than *M* capacity (Pascual-Leone, 1997, 2000).

Unlike some notions of working memory, *M* capacity is seen not as a distinct structural store but rather as a functional capacity to hyperactivate a limited set of task-relevant schemes. This is similar to notions of working memory as controlled attention, proposed by Cowan (2001), Engle (Engle, Tuholski, Laughlin, & Conway, 1999), and Ruchkin and colleagues (Ruchkin, Grafman, Cameron, & Berndt, in press; Pascual-Leone, in press). Pascual-Leone has discussed elsewhere similarities and distinctions between the construct of *M* capacity and, for example, Baddeley's notion of working memory (Baddeley, 2001; Pascual-Leone, 2000), Cowan's concept of mental storage capacity (Cowan, 2001; Pascual-Leone, 2001), and Halford's developmental notion of processing capacity (Halford, Wilson, & Phillips, 1998; Pascual-Leone, 1998).

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Pascual-Leone proposed that the activation power of  $M$  increases with maturation during normal development in childhood. When measured behaviorally, this capacity grows by one mental unit every 2 years, from a capacity of one at 3 to 4 years of age to a capacity of seven at 15 to 16 years and older (Johnson, Fabian, & Pascual-Leone, 1989; Pascual-Leone, 1970, 1987; Pascual-Leone & Baillargeon, 1994).

Intellectually gifted children generally score higher than their nongifted peers on working memory span measures (e.g., Saccuzzo, Johnson, & Guertin, 1994; Schofield & Ashman, 1987; Segalowitz, Unsal, & Dywan, 1992). These group differences usually have been attributed to greater efficiency in retrieval or encoding processes, to efficient strategy use, or to compactness of representations in long-term memory rather than to higher absolute capacity in gifted children (e.g., Borkowski & Peck, 1986; Dark & Benbow, 1991; Schofield & Ashman, 1987; Torgesen, Kistner, & Morgan, 1987).

Our  $M$  capacity measures are not span tasks because they have been designed to minimize effects of prior knowledge and to contain items that vary systematically in demand for  $M$  capacity (i.e.,  $M$  demand; Pascual-Leone & Ijaz, 1989; Pascual-Leone, Johnson, Baskind, Dworsky, & Severtson, 2000). Nevertheless, performance on these tasks is a function of both  $M$  capacity and other organismic factors, including specific and generic learning (e.g., strategies or executives; Miller, Pascual-Leone, Campbell, & Juckes, 1989; Pascual-Leone, Johnson, Baskind, et al., 2000; Pascual-Leone, Johnson, Bauer, & Cuning, 2000). Based on prior research in our lab (Pascual-Leone & Johnson, 1998; Pascual-Leone, Johnson, Baskind, et al., 2000), we predicted that older children would score higher than younger children and that gifted children would score higher than nongifted children on the  $M$  measures we employed.

### *Inhibitory Processes*

Inhibition is considered to be an important component of executive functioning (e.g., Carlson & Moses, 2001; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Zelazo, Carter, Resnick, & Frye, 1997). As currently used in the cognitive literature, inhibition refers to the central, active suppression of information that is irrelevant to the task at hand. This suppression can be interpreted as a mental-attentional interruption of schemes (e.g., Pascual-Leone, 1984, 2000). Although efficient inhibition has been proposed to distinguish academically gifted from nongifted children (e.g., Harnishfeger &

Bjorklund, 1994), research has not directly addressed inhibitory processes but rather has addressed metacognition, problem solving, or other task-specific modes of processing (e.g., decision making, Ball, Mann, & Stamm, 1994; analogical reasoning, Caropreso & White, 1994; transfer of strategies, Ferretti & Butterfield, 1992). A review of the literature (Alexander, Carr, & Schwanenflugel, 1995) showed inconsistent findings regarding the abilities of gifted children, particularly with respect to metacognition, and suggested that results of comparisons between gifted and nongifted children depend on the task being investigated. Gifted children outperformed their nongifted peers on tasks that appear to involve inhibitory processes, such as far transfer of strategies (ability to transfer strategies from seemingly different situations) or insightful problem solving (ability to solve problems in misleading situations; Alexander et al., 1995; Ferretti & Butterfield, 1992). Davidson and Sternberg 1984; Davidson, 1986; found that gifted children excelled in selective encoding of information, that is, ability to sift out relevant from irrelevant information. Thus, the existing research has not specifically addressed whether gifted children exhibit more efficient inhibition but has suggested that this hypothesis is tenable.

Inhibition is considered to be the active mental-attentional suppression of task-irrelevant information, whereas interference is the local cognitive competition between multiple schemes, which may prevent less strongly activated schemes from being accessed (Harnishfeger, 1995; Harnishfeger & Bjorklund, 1994). The term *inhibit* often is used to refer to the processes that occur in attention allocation and resistance to interference (e.g., Lane & Peterson, 1982; Schiff & Knopf, 1985), and developmental increase in resistance to interference has been used to argue for developmental growth in efficiency of inhibitory processes (e.g., Durston et al., 2002; Harnishfeger, 1995; Lorschach & Reimer, 1997). In the experimental literature, however, measures of efficiency of inhibition have not consistently been found to correlate with measures of degree of experienced interference (e.g., Fox, 1995; Houghton, Tipper, Weaver, & Shore, 1996; Neill, Valdes, & Terry, 1995; Tipper & Milliken, 1996), possibly because one may be able to deal with interference by means of bypass strategies that do not involve active inhibition of irrelevant schemes. We used negative priming (NP) tasks to measure efficiency of inhibition; and we measured susceptibility to interference with the Stroop task and Trail Making Test.

NP is a selective attention paradigm that has been used extensively to study inhibition in adults. In NP

tasks, pairs of stimuli (e.g., superimposed line drawings) are presented to individuals so that a response is required to one of the items (target) while the other item (distractor) must be ignored. Under conditions in which the distractor stimulus on trial  $n$  (the prime trial) becomes the target stimulus on trial  $n+1$  (the probe trial), reaction time (RT) to the target may be slowed. This delay in RT is called the negative priming effect (NP effect; Tipper, 1985; Tipper & Cranston, 1985). It is assumed that the process of responding to the target requires one to ignore the distractor, and this act of ignoring involves inhibition of the representation of the distractor stimulus (Houghton & Tipper, 1994; Tipper, 1985, 2001). Consequently, when the distractor stimulus becomes the target on the next trial, additional time is needed to bring the representation into activation, because the previous inhibition would have dampened its activation level. Degree of NP can thus serve as an index of strength of inhibition.

The NP effect has been shown to be robust and has been demonstrated with a wide variety of stimuli and response modalities (for reviews see Fox, 1995; May, Kane, & Hasher, 1995; Neill et al., 1995). The few studies that have used the NP paradigm with children have yielded mixed results. Tipper, for example, found that 7- to 8-year-old children did not exhibit NP in Stroop and picture-naming NP tasks, although adults did (Tipper, Bourque, Anderson, & Brehaut, 1989). Tipper and McLaren (1990), however, found that 5- to 6-year-olds exhibited NP to the same degree as 11- to 13-year-olds and adults when required to respond to the location of the target stimulus. Similarly, Simone and McCormick (1999) reported that 6- to 8-year-olds showed equivalent NP to adults in a task that required response to target location.

The complexity of the task and the extent to which it taps automatic versus effortful inhibition processes may determine the extent to which young children inhibit efficiently in NP and interference tasks. According to Pascual-Leone (1984, 2000; Pascual-Leone, Johnson, Goodman, Hameluck, & Theodor, 1981), automatic inhibition or interruption is released by allocation of  $M$  capacity to a set of task-relevant schemes; following this allocation of  $M$ , inhibition is applied automatically to any remaining activated schemes that are not being boosted by  $M$  and are seen by the participant as irrelevant to the task. This automatic inhibition eliminates from working memory task-irrelevant schemes, thus producing an act of selective attention. Automatic interruption may suffice in distracting situations, that is, situations that elicit schemes that are irrelevant to the intended

performance but do not interfere with the application of task-relevant schemes.

In highly misleading situations, irrelevant schemes are in direct competition with task-relevant schemes in the sense that they interfere with application of the relevant schemes. In this case, effortful inhibition or interruption is produced by executive processes to inhibit interfering schemes. Effortful interruption generally is applied to a situation, before the corresponding allocation of  $M$ , to facilitate the choice of schemes on which the  $M$  allocation will apply (Pascual-Leone, 1984, 1987, 1997). Nigg (2000) has made a similar distinction between what he has called automatic and executive inhibitory processes. We used NP and interference tasks that required automatic versus effortful inhibition (these tasks are described in the Method section). We predicted that gifted children (and older children) would exhibit more efficient inhibition than nongifted (and younger) children only on mentally demanding tasks that required effortful inhibition. The NP paradigm has not been used before with gifted children.

### *Speed of Processing*

Gifted (high IQ) children have been found to respond more quickly than nongifted (average IQ) children on a variety of information-processing tasks, including simple RT (Cohn, Carlson, & Jensen, 1985; Segalowitz et al., 1992), choice RT (Cohn et al., 1985; Kranzler, Whang, & Jensen, 1994), spatial discrimination (Kranzler et al., 1994), short-term memory scanning (Cohn et al., 1985), and synonym-antonym discrimination (Cohn et al., 1985). Differences between gifted and nongifted groups increase with increasing complexity on elementary cognitive tasks (Cohn et al., 1985; Kranzler et al., 1994). At the same time, group differences are sometimes absent if the task is too simple (e.g., simple RT; Kranzler et al., 1994; Saccuzzo et al., 1994) or too difficult (e.g., very short stimulus duration; Saccuzzo et al., 1994). Dark and Benbow (1991) found that speed in a lexical decision task was associated with type of exceptionality: Verbally precocious adolescents were faster than those who were mathematically (but not verbally) precocious.

Some authors have interpreted such group differences on speeded tasks as evidence that intellectually gifted children differ from average children in speed and efficiency of elementary cognitive processes (e.g., Cohn et al., 1985; Kranzler et al., 1994). Other authors, in contrast, have suggested that the observed differences in speed of responding may reflect variations in attention, motivation, organiza-

tion of long-term memory, prior learning, or executive processes (e.g., Brewer, 1987; Dark & Benbow, 1991; Geary & Brown, 1991).

Gifted children do not always respond more rapidly than their nongifted peers, and there is evidence that gifted children strategically moderate their speed of responding. Sternberg (1977; Sternberg & Davidson, 1982), for example, found that high intelligence was associated with longer encoding times on reasoning problems. Geary and Brown (1991) found that gifted children were more accurate than nongifted children at solving single-digit addition problems and were more likely to use a memory retrieval strategy, but they were not faster at retrieving answers from long-term memory. Reams, Chamrad, and Robinson (1990) examined three subtests of the Wechsler Intelligence Scale for Children–Revised (WISC–R), on which bonus points are given for rapid responses, and found that high-IQ children received more speed points than did average-IQ children on only one of the subtests. The authors suggested that “higher capacity need not always be reflected in faster performance” on insight problems (Reams et al., 1990, p. 110).

Our NP and interference paradigms all were speeded. We predicted that gifted children would respond more rapidly on these. Consistent with the current developmental literature (e.g., Kail, 1988, 1991), we also expected that older children would respond more quickly than younger children. The *M*-capacity tasks were not speeded, but response times were recorded on one of these measures (the figural intersections task [FIT]). Because the FIT is a problem-solving task requiring complex processing, we expected that gifted children’s response times would be at least as long as those of nongifted children. Consistent with our prior research, we expected that younger children would have equivalent response times to older children for FIT items within their *M* capacity but that younger children would respond more quickly (i.e., less reflectively) once the items exceeded their capacity.

### *Current Study*

The current study examined performance on measures of *M* capacity, inhibition or susceptibility to interference, and speed of processing to determine whether academically gifted children were advanced for their age in these basic cognitive processes. Our design also allowed us to examine age differences on these tasks, in both gifted and mainstream samples. In addition, we were interested in examining the stability of each construct across

multiple measures. We predicted correlations among measures requiring effortful inhibition, but not necessarily between measures of effortful versus automatic inhibition. We also examined the extent to which age and group differences on *M* capacity measures could be accounted for by measures of inhibition and speed of processing.

## Method

### *Participants*

Fifty-seven gifted and 92 mainstream children were recruited from three public schools in generally middle-class, suburban neighborhoods. The sample was ethnically diverse and included White children, Black children, and children from families of, for example, East Indian and Chinese origins. Children in the gifted group were in full-time programs for academically gifted students. The younger sample was composed of students from Grades 1 to 3: 17 from the gifted program and 35 from a mainstream academic program, for children who had not been identified as gifted. The older sample was composed of students from Grades 4 and 5: 40 from the gifted program and 57 from a mainstream academic program. Table 1 gives details on the age and gender distributions for the samples.

At the primary level (Grades 1–3), children gained admission into the gifted program if their Verbal, Performance, or Full-Scale IQ on the Wechsler Intelligence Scale for Children–Third Edition (WISC–III) was in the 99th percentile. At the junior level (Grades 4–5), children gained admission if their Verbal, Performance, or Full-Scale IQ on the WISC–III was in the 97th percentile, or if in boardwide testing at Grade 4 they met criteria set by the school board. Boardwide testing involved the Canadian Cognitive Abilities Test (CCAT), followed by the Canadian Achievement Test–2 for students with sufficiently high scores on the CCAT.

IQ testing was conducted by a school psychologist or a private psychologist at the request of the parent or the school. Boardwide testing with the CCAT involved all Grade 4 students; thus, all students were evaluated for admission to the junior gifted program. Gifted and mainstream children were in separate classes in the same schools; thus, the mainstream sample was composed of students not selected by the school board for the gifted program. We distributed letters of parental consent to all students in the appropriate grades and included in the study those who received consent. Children with learning disabilities were excluded.

Table 1  
Mean Age and Sex Distribution of Gifted and Mainstream Samples

	Younger				Older			
	Gifted <i>n</i> = 17		Mainstream <i>n</i> = 35		Gifted <i>n</i> = 40		Mainstream <i>n</i> = 57	
	M	SD	M	SD	M	SD	M	SD
Age (years)	8.05	0.84	8.27	0.76	10.64	0.61	10.42	0.62
Range	(6.83–9.17)		(6.75–9.25)		(8.67–11.92)		(9.33–11.33)	
Sex ( <i>n</i> )	Boys 12	Girls 5	Boys 22	Girls 13	Boys 28	Girls 12	Boys 29	Girls 28

### Measures

**M-capacity tasks.** Children completed a computer-based version of the FIT—a well-studied measure of *M* capacity (Baillargeon, Pascual-Leone, & Roncadin, 1998; Pascual-Leone & Baillargeon, 1994; Pascual-Leone & Ijaz, 1989; Pascual-Leone & Johnson, 2001). The task involved finding the area of common intersection of a number of overlapping, geometric shapes. Figure 1 shows a sample FIT item. Each item (i.e., stimulus presentation) of the FIT consisted of two to eight shapes that were nonoverlapping on the right-hand side of the computer screen and overlapping on the left-hand side. A page corresponding to the screen display was placed in front of the child on a computer drafting tablet. The child used an electronic pen to make his or her responses on the tablet, and the responses appeared as dots inside the corresponding figures on the screen (a beep indicated that the response had been registered). In the context of eight training items, children were taught the rules for solving the task: Place a dot inside each discrete shape on the right, and then place a single dot in the area of common intersection of the relevant overlapping shapes on the left.

The number of discrete shapes on the right indicated the class of an item (e.g., four shapes indicated a Class 4 item, two shapes indicated a Class 2 item, etc.; Figure 1 illustrates a Class 5 item). There were 4 items in each of Classes 2 and 8, 6 items in each of Classes 3 through 6, and 5 items in Class 7, for a total of 37 items. Children in Grade 1 were not given Class 8 items; therefore, they completed 33 items. Each child received the items in the same random order.

The program recorded response latencies (in milliseconds) from the moment the child placed

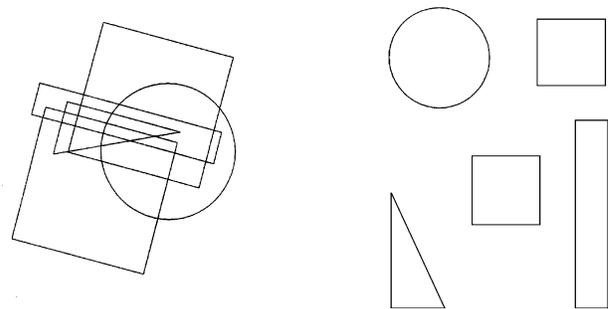


Fig. 1. Example of a Class 5 item from the figural intersections test (FIT).

the last dot inside a figure on the right-hand side to the moment he or she placed a dot inside an intersection area on the left-hand side. We computed mean latencies for each item class, as well as the mean latency across all items.

The total number of correct responses was rescaled into a FIT-*M* score, which could range from 1 to 8. Total performance score was assimilated to a theoretical distribution constructed on the assumption that a child would pass only those items that had an *M* demand equal to or less than his or her *M* capacity. The *M* demand of a task corresponds to the maximum number of schemes that must be kept activated simultaneously by *M* capacity to solve the task. In the case of the FIT, the *M* demand of an item corresponds to the item class. The FIT-*M* score (elsewhere called the SIT score) has been shown to have high validity and reliability (Pascual-Leone, Baillargeon, Lee, & Ho, 1990; Pascual-Leone & Ijaz, 1989; Pascual-Leone & Johnson, 2001).

The second *M* capacity measure was the compound stimuli visual information (CSVI) task (Johnson et al., 1989; Pascual-Leone, 1970). Children were trained to associate each of nine visual cues (e.g., square, red, etc.), which were presented on a card,

with a corresponding motor-action response (e.g., raising hand, clapping hands, etc.). We trained children on the nine simple stimulus-response associations until they achieved 30 consecutive correct responses. They then received test items (compound stimuli) that contained two to eight visual cues per card. The compound stimuli were arranged such that each cue (e.g., square, red, dotted background, or x) was nested within the others (e.g., a red square with an x in the middle, against a dotted background). Participants were told to respond to as many cues as were present. The tester presented each card for 6 s and allowed the child to respond during and after this time. Item class was defined by the number of cues present in the compound stimuli card. Forty-two items (six in each of Item Classes 2–8) were presented in random order.

A well-supported mathematical model was used to calculate CSVI-M scores (ranging from 1 to 8) on the basis of item class and the number of cues to which a child responded correctly (Pascual-Leone, 1970, 1978). The CSVI has high validity and reliability (Johnson et al., 1989; Pascual-Leone, 1970; Pascual-Leone & Ijaz, 1989).

*Tasks measuring speed of processing and cognitive inhibition or susceptibility to interference.* The spatial location task, a computer-based NP task, yielded measures of automatic inhibition and speed of processing. Tipper and his colleagues designed and have studied this task (Milliken, Tipper, & Weaver, 1994; Tipper, Weaver, & Houghton, 1994; Tipper, Weaver, & Milliken, 1995). Four locations on the computer screen (top, bottom, left, and right) were indicated by small boxes (1.25 cm × 1.25 cm). In each item, an uppercase colored X (1 cm high) appeared in two of the boxes, along with a color patch (ASCII character 254: 0.5 cm × 0.5 cm) in the center of the display (see Figure 2). The possible colors were blue, green, yellow, and purple. The task was to move a digital joystick as quickly as possible in the direction of the X (target) that matched the color of the central cue while ignoring the X (distractor) that did not match the cue. Instructions emphasized both speed and accuracy. A click signaled correct responses, whereas a beep signaled incorrect responses.

Each trial consisted of a prime-probe pair. The individual was prompted by a message on the screen to push a button to start each trial. Immediately after the button press, four boxes appeared on the screen and remained on for the duration of the trial. After a delay of 1,000 ms, the prime stimuli (target and distractor) appeared each in a different randomly chosen box, along with the central color cue. The stimuli remained on the screen until the

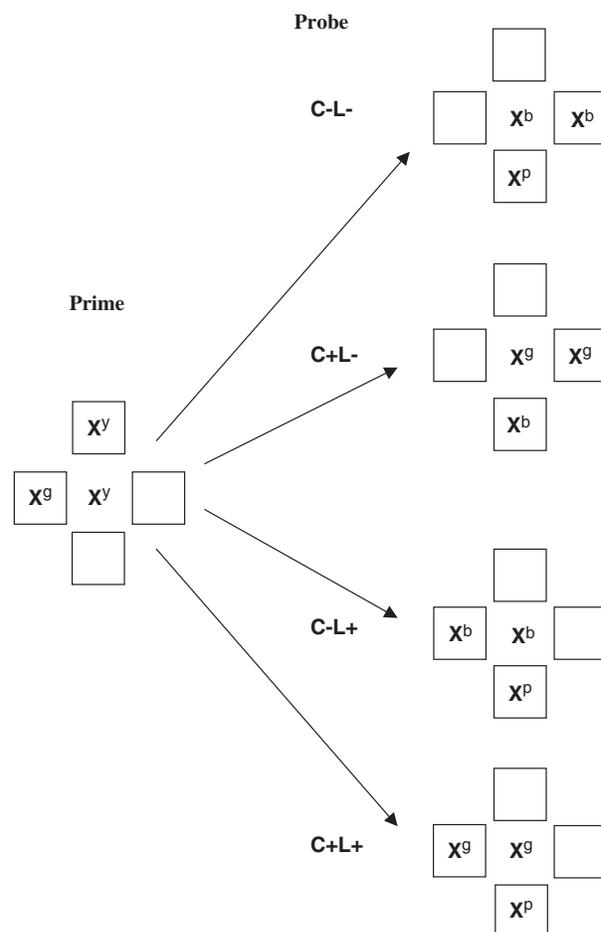


Fig. 2. Illustration of the four possible conditions in the spatial location task. Lowercase letters indicate color of stimuli: y = yellow, g = green, b = blue, p = purple.

individual responded (or until 3,000 ms had passed). After a 500-ms interstimulus interval, the probe stimuli (target and distractor) and color cue appeared simultaneously and remained on until the individual responded (or until 3,000 ms had passed). There were 243 trials, of which the first 27 were practice trials. The task was run in blocks of 81 trials, with 30 s breaks between blocks. Total testing time was about 15 min. The program recorded the accuracy and latency of each response.

The probe distractor always appeared in a location and color that had not been used in the preceding prime. There were four conditions defined by the relationship between the prime distractor and the probe target (see Figure 2). The probe target could be in the same (C+) or different (C-) color as the prime distractor. Independently, the probe target could be in the same (L+) or different (L-) location as the prime distractor. The control condition was defined by the C-L- condition (96 trials), in which there

was no relationship between the prime and probe items (i.e., they did not match in color or location). The other three conditions were: (a) C-L+ (different color, same location; 48 trials), (b) C+L- (same color, different location; 48 trials), and (c) C+L+ (same color and location; 24 trials).

On average, children responded correctly on 94% of the trials. The program calculated median latencies (in milliseconds) for each condition and for the primes, for correct responses only. We used medians to be consistent with results reported by Tipper. In research with adults, Tipper found that median latencies in the C+L+ and C-L+ conditions were significantly longer than in the C+L- or C-L- conditions (Tipper et al., 1994; Tipper et al., 1995). That is, an NP effect was found when the probe target was in the same location as the previous prime distractor.

We used the spatial location NP task as a measure of efficiency of automatic inhibition. In this task the distractor stimulus was spatially separated from the target and created a distracting, but not a misleading, situation. The application of controlled attention (i.e., *M* capacity) to the target should result in automatic inhibition of the scheme for the distractor (Pascual-Leone, 1984; Pascual-Leone et al., 1981). This automatic attentional inhibition eliminates from working memory task-irrelevant schemes, thus producing an act of selective attention. Effortful inhibition of the distractor before application of *M* capacity to the target scheme is not needed, however, because target and distractor are distinct, separate, and perceptually overlearned. Given the low mental demand of this task and the hypothesis that it elicits automatic inhibition, we did not predict any group or age differences in degree of NP on the spatial location task. Median RT to the prime stimuli provided a measure of speed of processing in a perceptual-motor choice RT task.

A version of the Stroop task (Stroop, 1935) yielded measures of speed, effortful inhibition, and susceptibility to interference. This version, developed by Dalrymple-Alford and Budayr (1966) and Tipper et al. (1989), included an ignored repetition (IR) condition that has been found to yield longer latencies than the standard Stroop interference condition (i.e., an NP effect indicating efficient effortful inhibition). Individuals were presented with a series of color words (black, blue, green, red, orange, and yellow) printed on a page and were required to quickly name aloud the color of ink the words were written in. For example, the individual had to say "blue" in response to the word *yellow* written in blue ink. The task consisted of three conditions: (a) neutral (rows of

three to six Xs were presented in different colors), (b) Stroop (color words were written in incongruent ink colors, and there was no relationship between adjacent items), and (c) IR (throughout the list, each word was printed in the color of the word that preceded it, e.g., the word *blue* printed in yellow would be followed by the word *orange* printed in blue, followed by the word *black* printed in orange, etc.).

Because the reading response is activated automatically, the color-word scheme competes with the ink-color scheme at the response level, resulting in a delay in responding—this is the Stroop effect. This response competition may be resolved by inhibiting the color-word response. This inhibition is effortful because the word and ink color are integrated in a single stimulus, and their corresponding perceptual and cognitive schemes are both highly activated initially. Residual effects of this inhibition can be gauged by response latency in the IR condition: If the color word response (e.g., blue) on trial *n* was inhibited (i.e., its scheme interrupted and blocked from the response), there should be a further delay (beyond that of the Stroop condition) when it becomes the proper label for the ink color in the next item—this is the NP effect.

For each of the three conditions, stimuli were printed on three 8.5 in. × 11 in. sheets. Each sheet contained 30 items (three columns of 10 items printed in bold 26-point Arial font) that were centered on the page. The items also were centered in each column, 10 cm apart, with 1.2 cm between items within the same column. Children first received a color verification sheet (Xs written in the colors black, blue, green, red, orange, and yellow) to check for color vision and ensure that they used the desired color labels. This was followed by a practice sheet with three columns (10 items per column), one for each condition. Three test sheets for each task condition were then presented in the following order: neutral-1, Stroop-1, IR-1, IR-2, Stroop-2, neutral-2, neutral-3, Stroop-3, and IR-3. Instructions emphasized both speed and accuracy. The tester used a digital stopwatch to time latency to complete naming of the stimuli on each card and recorded errors in color naming. Latency (in seconds) and error score for each condition (neutral, Stroop, and IR) were averaged across the three cards for each condition. The Stroop effect is evidenced by a longer latency in the Stroop condition than in the neutral condition; this provides a measure of susceptibility to interference. Longer latency in the IR condition, compared with the Stroop condition, is evidence of NP—an index of effortful inhibition. Latency in the neutral condition provides a measure

of speed in a simple color-naming task. If gifted children have superior control over effortful inhibition processes, they should show a smaller Stroop effect and a greater NP effect than their mainstream peers. A similar pattern of differences is expected for the contrast between older and younger children.

The Children's Trail Making Test (Reitan, 1992) also provided measures of speed and susceptibility to interference. Part A of the test was composed of 15 circled numbers (i.e., 1 to 15) randomly distributed on a page. The child used a pencil to connect the circles in numbered order from 1 to 15 as rapidly as possible. If an error was made, the child was stopped, corrected, and instructed to continue at the last correct circle. Part B consisted of 15 circles that contained the numbers 1 to 8 and the letters A to F. The task was to connect quickly the circles in order, alternating between numbers and letters (i.e., 1-A-2-B-3-C, etc.). For each part the score was the total time (in seconds) taken to connect all the circles, including time taken to correct errors. A difference score (Part B – Part A) also was calculated to reflect the additional time required for the alternating task.

The Children's Trail Making Test has been used as a measure of attention and executive function (see Morris, 1996, for brief review) and is part of a battery of neuropsychological tests often administered to children (Rourke, Bakker, Fisk, & Strang, 1983). Nielson, Langenecker, and Garavan (2002) found that the Trail Making score correlated with performance on a response-inhibition task in older adults. In the current study, it provided a measure of susceptibility to interference, in the context of a complex task requiring effortful inhibition. Effortful inhibitory processes are involved in Part B of the task because the child must alternate between two well-learned, distinct sequences that normally do not alternate or relate. Activation of number and letter schemes is required for successful task performance; however, successful performance also requires alternating between these two different types of schemes; therefore, momentary effortful inhibition is required to shift from numbers to letters and vice versa. The task may also provide an index of the sophistication of one's executive for controlling mental attention, because it requires a fairly complex interplay of activation and inhibition processes. Having responded to a number, there is an overlearned habit to continue with the number sequence. One must inhibit this operative tendency in order to respond to the next letter. At the same time, one should not inhibit the number itself, because it will be needed later to cue the correct place in the number sequence.

Spren and Strauss (1998) reported that Trail Making performance is significantly correlated with IQ in adults; however, Segalowitz et al. (1992) found that a group of gifted seventh graders did not exhibit less interference than a group of nongifted peers. If gifted children have better control over their capacities to activate and inhibit schemes, we should expect them to exhibit less interference (i.e., a lower Part B – Part A difference score) than their mainstream peers. Consistent with past research (e.g., Reitan, 1971; Spren & Strauss, 1998), we also predicted that younger children would experience more interference than older children. Latency on Part A (connecting numbers) provides a measure of speed in a task requiring visual search and simple motor sequencing.

Because we predicted group differences in overall speed of responding on the inhibition and interference tasks, it is important to determine whether any differences observed in the inhibition and interference scores might be accounted for by processing speed. Following a method used by Christ, White, Mandernach, and Keys (2001), for each task described in this section we computed a transformed score that corresponded to latency in the inhibition or interference condition minus latency in the control condition, divided by latency in the control condition. This scales the difference by the control response time and controls for group or age differences in processing speed.

### *Procedure*

Participants were tested in four sessions. The tasks were administered in the following order: (a) computer FIT, (b) CSVI, (c) Children's Trail Making Test and spatial location task, and (d) Stroop task. Note that the *M*-capacity tasks were nonspeeded, and instructions for these tasks emphasized accuracy only. In the Trail Making, Stroop, and spatial location tasks, children were told to work as quickly and as accurately as they could. Sessions took place in the participants' schools during school hours. Children did not participate in more than one session per day; sessions were separated by 2 to 5 days. All participants completed all tasks.

## **Results**

### *Preliminary Issues*

Before analyses, we examined data distributions for normality and sphericity. For variables that violated sphericity, we used the Huynh-Feldt

adjusted  $F$  test. Several variables were not normally distributed (i.e., had significantly skewed distributions); different transformations were applied on these variables, which resulted in improved distributions that were normal or approximately normal. We conducted parallel analyses using the transformed and nontransformed variables. Because results were the same for both sets of analyses (with one exception, in the Stroop task, described later), we report results for the nontransformed variables for ease of interpretation. For all continuous variables, group differences were analyzed using a 2 (group: gifted vs. mainstream)  $\times$  2 (age: younger vs. older) analysis of variance (ANOVA) with repeated measures where appropriate. A Bonferroni correction was used when conducting multiple within-group contrasts.

There were proportionally more boys than girls in the gifted samples, as compared with the mainstream samples. This generally reflected the proportions in the classrooms. To examine possible effects of a confounding of sex with group, we initially performed a Group  $\times$  Age  $\times$  Sex analysis on data from each task. There were no main or interaction effects involving the sex factor, except for the spatial location task. Thus, in the analyses reported, we retained the sex factor only for this task.

For tasks involving speeded responses, we examined the latency distribution for each dependent variable. We dropped participants from analyses on a particular task if their latency was greater than 3  $SD$  from the mean for their age group. Specifically, one older mainstream and one young gifted participant were dropped from analyses of the spatial location task, three mainstream participants (two older and one young) and one young gifted participant were dropped from the Stroop task, and two mainstream participants (one older and one young) and one young gifted participant were dropped from the Trail Making Test.

#### *M-Capacity Measures*

Means and standard deviations for  $M$  scores derived from the FIT and CSVI appear in Table 2. Analysis of the FIT indicated main effects for group,  $F(1, 145) = 20.77$ ,  $MSE = 1.02$ ,  $p < .0001$ , and age,  $F(1, 145) = 35.50$ ,  $p < .0001$ , but no interaction,  $F < 1$ . The CSVI yielded the same pattern: main effects for group,  $F(1, 145) = 16.69$ ,  $MSE = 1.22$ ,  $p < .0001$ , and age,  $F(1, 145) = 19.37$ ,  $p < .0001$ . As predicted, gifted children scored higher than mainstream children and older children scored higher than younger on both measures. Mean scores for the mainstream

samples were consistent with age-based theoretical predictions (Pascual-Leone, 1970), but the gifted samples scored one  $M$  level higher than predicted for the total population.

#### *Measures of Inhibition and Speed of Processing*

*Spatial location task.* In this task, the child moved a joystick in the direction of an X that matched a central color cue while ignoring a second X in a nonmatching color. Median latencies for error-free trials are shown in Figure 3. The prime condition reflects response time for the first stimulus item of each pair; it indexes orienting response and latency on a choice RT task. There were significant group,  $F(1, 143) = 24.22$ ,  $p < .0001$ , and age,  $F(1, 143) = 50.23$ ,  $MSE = 12608.22$ ,  $p < .0001$ , effects for prime latency. Gifted children were faster than their mainstream peers, and older children were faster than younger children.

Conditions labeled with C and L in Figure 3 reflect response latency to the second item (i.e., probe) of each pair. Based on previous research (e.g., Tipper et al., 1995), we expected longer latencies in the L+ than in the L- conditions; this would provide evidence for spatial NP. We considered that NP in this task would reflect automatic inhibition; therefore, we did not expect any group or age differences in degree of NP.

We examined median latencies with a 2 (group)  $\times$  2 (age)  $\times$  2 (sex)  $\times$  2 (color: same C+ vs. different C-)  $\times$  2 (location: same L+ vs. different L-) repeated measures ANOVA. There were main effects for group,  $F(1, 139) = 19.03$ ,  $MSE = 55256.78$ ,  $p < .0001$ , and age,  $F(1, 139) = 50.91$ ,  $p < .0001$ . Across conditions, gifted children were faster than mainstream children, and older children were faster than younger children. There were within-subjects main effects for color,  $F(1, 139) = 4.75$ ,  $MSE = 2407.73$ ,  $p < .04$ , and location,  $F(1, 139) = 146.44$ ,  $MSE = 2413.09$ ,  $p < .0001$ . Overall, latencies were longer when the target matched the previous distractor in either location or color.

There was an interaction for Color  $\times$  Location,  $F(1, 139) = 12.27$ ,  $MSE = 1823.44$ ,  $p < .001$ . This and the main effects were qualified by a number of interaction effects, none of them involving the group factor. We examine first interactions involving age: Age  $\times$  Location,  $F(1, 139) = 8.01$ ,  $p < .01$ , and Age  $\times$  Color  $\times$  Location,  $F(1, 139) = 5.99$ ,  $p < .02$ . For both age groups, latencies did not differ between the C-L- and C+L- conditions, and latencies in the L+ conditions were significantly longer than in the L- conditions. This is evidence of the predicted spatial

Table 2  
Mean Scores as a Function of Age and Group

	Young Gifted		Young Mainstream		Older Gifted		Older Mainstream		Effect Size	
	M	SD	M	SD	M	SD	M	SD	Age	Group
<i>M</i> measures										
FIT- <i>M</i>	4.41	1.37	3.69	0.96	5.60	0.74	4.67	1.07	.18	.10
CSVI- <i>M</i>	4.24	1.15	3.26	0.82	4.95	1.20	4.30	1.18	.11	.09
Spatial location (ms)										
Prime	782.69	111.94	871.08	117.15	624.35	96.47	738.20	119.50	.23	.11
NP effect	54.50	61.20	61.46	85.50	42.56	35.14	47.74	46.13	.01	.00
Stroop RT (sec)										
Stroop effect	19.07	7.10	23.81	8.36	12.74	4.57	15.22	3.89	.24	.06
NP effect	-1.02	5.28	1.78	6.64	2.34	3.45	2.58	4.00	.04	.02
Stroop errors										
Neutral	0.06	0.13	0.12	0.23	0.18	0.29	0.11	0.20	.01	.00
Stroop	1.35	1.30	1.82	1.38	0.79	0.63	1.48	2.11	.02	.03
IR	1.15	0.93	2.08	1.47	0.92	0.70	1.48	1.29	.02	.08
Trail B - A (sec)	19.88	8.72	39.53	25.48	13.45	7.25	24.00	11.64	.08	.16

Note. *M* measure = mental-attentional measure; FIT-*M* = figural intersections task *M* score; CSVI-*M* = compound stimuli visual information *M* score; NP = negative priming; RT = reaction time; IR = ignored repetition; Trail B - A = Children's Trail Making Test difference score. Effect size =  $\eta^2$ , proportion of total variance accounted for by the age or group main effect. Higher scores on the *M* measures indicate better performance. Higher scores on other measures indicate longer latency, stronger effect of distractors on latency, or greater number of errors.

NP effect at both ages. In older children, latencies were of similar magnitude in the C-L+ and C+L+ conditions, but in younger children, latencies were longer in C+L+ as compared with C-L+, a result also found with adult participants (Johnson, Im-Bolter, & Pascual-Leone, 2003). This suggests that younger children had enhanced NP when the probe target matched the prime distractor in both features—color and location.

There were also several interactions involving sex: Sex  $\times$  Location,  $F(1, 139) = 13.27, p < .001$ ; Sex  $\times$  Location  $\times$  Color,  $F(1, 139) = 4.87, p < .03$ ; and Age  $\times$  Sex  $\times$  Location,  $F(1, 139) = 5.14, p < .03$ . For both sexes, latencies did not differ between the C-L- and C+L- conditions, and latencies in the L+ conditions were significantly longer than in the L- conditions (i.e., both sexes showed NP). The contrast between the C+L- and C-L+ conditions was greater for females than for males. When results were examined as a function of age and sex, it was found that young and older children of both sexes exhibited NP to location, but that this effect was of greatest magnitude in the young female participants.

We also performed an ANOVA on the transformed NP score. This score was equal to the mean of latencies in the C+L+ and C-L+ conditions, minus latency in the control C-L- condition; this

difference was then divided by the C-L- latency. This analysis yielded no group or age effects. This is consistent with the finding, reported earlier, that the NP effect did not differ as a function of age group or academic stream. There was, however, a main effect for sex,  $F(1, 139) = 4.22, MSE = 0.00514, p < .05$ . Females ( $M = 0.081, SD = 0.076$ ) showed greater NP than did males ( $M = 0.062, SD = 0.067$ ) on this score.

*Stroop task.* Mean latencies for the Stroop task are plotted in Figure 4. Longer latency in the Stroop condition versus the neutral condition would indicate interference from the misleading color words in the former condition. Longer latency in the IR condition versus the Stroop condition would indicate NP—a carryover effect of inhibition of the color word in the previous item. We considered that efficient performance on the Stroop task would require effortful inhibition. We therefore predicted that gifted children and older children would exhibit less of a Stroop effect and greater NP than mainstream and younger children.

A 2 (group)  $\times$  2 (age)  $\times$  3 (condition) ANOVA yielded main effects for group,  $F(1, 141) = 24.83, MSE = 144.51, p < .0001$ ; age,  $F(1, 141) = 70.75, p < .0001$ ; and condition,  $F(2, 282) = 821.85, MSE = 16.38, p < .0001$ . Overall, gifted children responded more quickly than mainstream children, and older

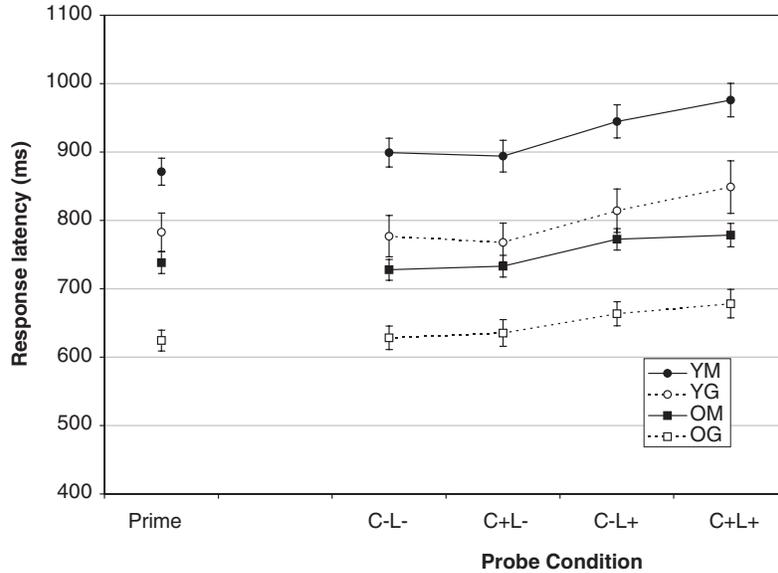


Fig. 3. Mean of median response latencies for prime and probe conditions of the spatial location negative priming (NP) task as a function of age and group (bars represent standard error). The probe target could share (C+) or not share (C-) the color of the prime distractor, and could share (L+) or not share (L-) the location of the prime distractor. Longer latencies in the L+ than in the L- conditions is indicative of spatial NP. YM = young mainstream sample, YG = young gifted, OM = older mainstream, OG = older gifted.

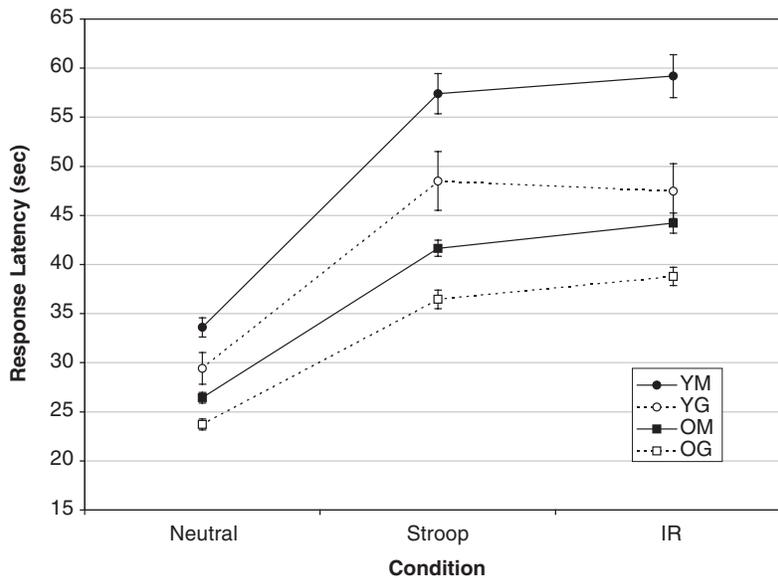


Fig. 4. Mean response latencies as a function of condition, age, and group on the Stroop task (bars represent standard error). YM = young mainstream sample, YG = young gifted, OM = older mainstream, OG = older gifted, IR = ignored repetition.

children responded more quickly than younger children. Across groups, latencies were longer in the Stroop condition ( $M = 44.67, SD = 11.55$ ) than in the neutral condition ( $M = 27.69, SD = 5.90$ )—evidence of Stroop interference—and longer in the IR condition ( $M = 46.60, SD = 11.74$ ) than in the Stroop condition—this is the NP effect.

The main effects were qualified by interactions for Group  $\times$  Condition,  $F(2, 282) = 12.56, p = .0001$ , and Age  $\times$  Condition,  $F(2, 282) = 26.81, p = .0001$ . As predicted, the mainstream group exhibited a greater Stroop effect (Stroop - neutral) than did the gifted group, and younger children experienced more Stroop interference than did older children. For NP

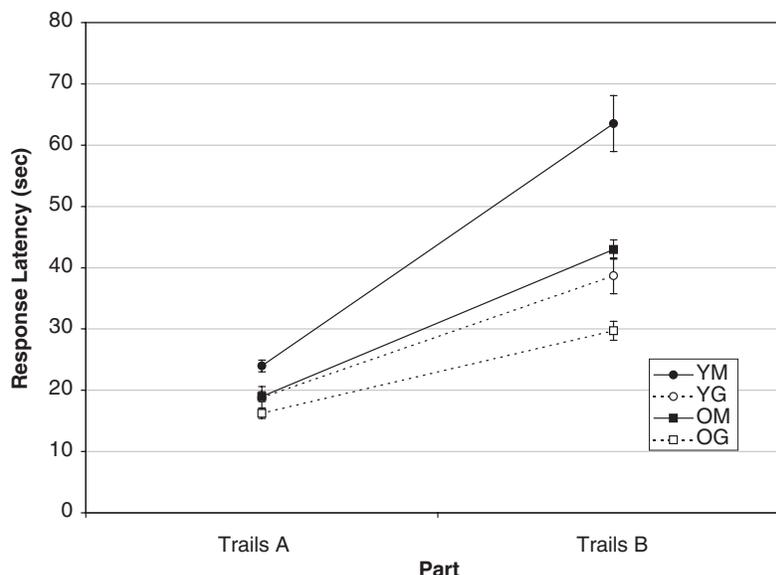


Fig. 5. Mean response latencies as a function of condition, age, and group on the Trail Making Test (bars represent standard error). YM = young mainstream sample, YG = young gifted, OM = older mainstream, OG = older gifted.

(IR – Stroop), however, only the predicted age effect was supported: Older children exhibited NP but younger children did not. Means for these difference scores appear in Table 2. Analysis of data transformed to correct for non-normality failed to yield a Group  $\times$  Condition effect.

We also examined Stroop and NP difference scores transformed to control for differences in speed in simple color naming. The transformed Stroop score was equal to:  $(\text{Stroop\_time} - \text{neutral\_time}) / \text{neutral\_time}$ . A two-way ANOVA yielded a main effect for age,  $F(1, 141) = 11.34$ ,  $MSE = 0.036$ ,  $p < .01$ , with young children scoring higher ( $M = 0.69$ ,  $SD = 0.21$ ) than older children ( $M = 0.57$ ,  $SD = 0.18$ ). There were no significant effects involving group. When differences in speed of color naming (in the nondistracting neutral condition) were removed from the Stroop interference score, the age effect remained, but the group effect was eliminated. This suggests that the greater Stroop effect originally reported for the mainstream children may be due to slower speed in simple color naming. The greater Stroop effect in younger children cannot be attributed to this, however.

The transformed NP score was equal to:  $(\text{IR\_time} - \text{Stroop\_time}) / \text{Stroop\_time}$ . Analysis yielded a main effect for age,  $F(1, 141) = 8.91$ ,  $MSE = 0.010$ ,  $p < .01$ , with older children ( $M = 0.07$ ,  $SD = 0.09$ ) scoring higher than young children ( $M = 0.02$ ,  $SD = 0.11$ ). Thus, the age difference in NP cannot be explained by differences in latency in the Stroop condition.

Mean number of errors on the Stroop task are reported in Table 2. Analysis of errors yielded main effects for group,  $F(1, 145) = 8.08$ ,  $MSE = 2.06$ ,  $p < .01$ , and condition,  $F(2, 290) = 78.07$ ,  $MSE = 0.84$ ,  $p < .0001$ , as well as a Group  $\times$  Condition interaction,  $F(2, 290) = 5.70$ ,  $p < .01$ . There were fewer errors in the neutral condition than in other conditions. Gifted children had fewer errors than mainstream children in the Stroop and IR conditions, but not in the neutral condition. Thus, gifted children were better able to control or avoid interference from incompatible color words.

*Trail Making Test.* Mean latencies on the Trail Making Test are plotted in Figure 5. Part A of the test required the child to connect symbols corresponding to a well-learned sequence (the numbers 1–15). Part B required the child to interleave two well-learned sequences (letters and numbers). We considered that effortful inhibition would be required to shift efficiently between letters and numbers in part B; therefore, we expected that gifted children and older children would experience less interference in Part B.

A 2 (group)  $\times$  2 (age)  $\times$  2 (part) ANOVA yielded main effects for group,  $F(1, 142) = 43.21$ ,  $MSE = 181.26$ ,  $p < .0001$ ; age,  $F(1, 142) = 28.16$ ,  $p < .0001$ ; and part,  $F(1, 142) = 308.07$ ,  $MSE = 112.97$ ,  $p < .0001$ . Overall, gifted children had shorter latencies than mainstream children, and older children had shorter latencies than younger children. For all groups, Part B took longer than Part A. As predicted, there were interactions for Group  $\times$  Part,  $F(1,$

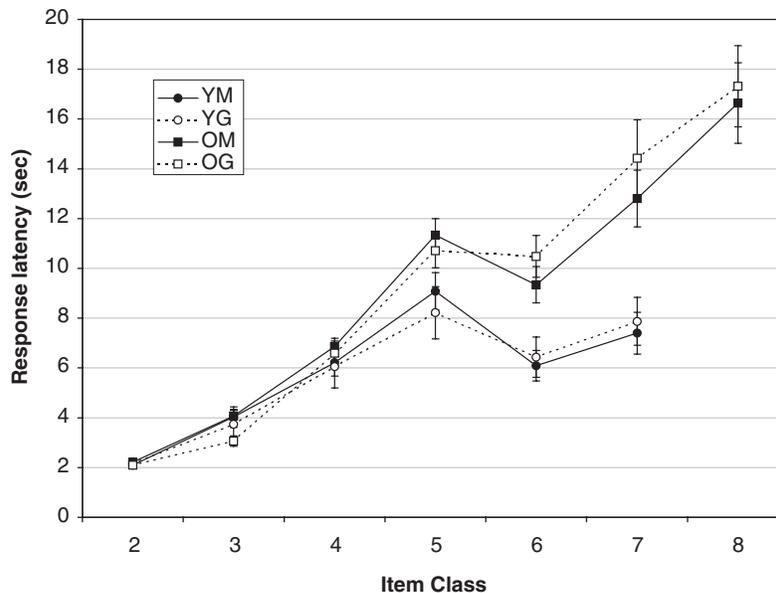


Fig. 6. Mean response latencies as a function of item class, age, and group on the figural intersection task (FIT; bars represent standard error). YM = young mainstream sample, YG = young gifted, OM = older mainstream, OG = older gifted.

142) = 29.96,  $p < .0001$ , and Age  $\times$  Part,  $F(1, 142) = 15.83$ ,  $p < .0001$ . The Part B – Part A differential was greater for mainstream children than for gifted children and greater for younger children than for older children (see Table 2). There also was an Age  $\times$  Group interaction,  $F(1, 142) = 4.01$ ,  $p < .05$ . Young gifted and older mainstream children did not differ in latency, averaged over the two parts of the test.

The transformed Trail Making difference score was equal to: (Trail B – Trail A)/Trail A. A two-way ANOVA yielded a main effect for group,  $F(1, 142) = 11.31$ ,  $MSE = 0.740$ ,  $p < .01$ , but no effects involving age. Gifted children experienced less interference on Trail B ( $M = 0.98$ ,  $SD = 0.56$ ) than did mainstream children ( $M = 1.54$ ,  $SD = 1.01$ ). Thus, latency on Trail A may account for age differences in slowing on Trail B, but this does not account for the gifted advantage on Trail B.

*FIT latencies.* Mean response latency for each FIT item class is plotted in Figure 6. Research has found that longer latencies are associated with better FIT performance, particularly in the higher item classes (Pascual-Leone, Johnson, Bauer, et al., 2000). A 2 (group)  $\times$  2 (age)  $\times$  6 (item class) ANOVA yielded main effects for age,  $F(1, 145) = 12.61$ ,  $MSE = 61.80$ ,  $p < .001$ , and class,  $F(5, 725) = 120.91$ ,  $MSE = 11.63$ ,  $p < .0001$ . Overall, younger children responded more quickly than older children. Across groups, latency increased with each successive increase in item class, with the exception of Classes 5 and 6, which did not

differ. There was an Age  $\times$  Class interaction,  $F(5, 725) = 15.86$ ,  $p = .0001$ . There were no differences in latencies between younger and older children for lower item classes (i.e., Classes 2–4); however, older children had longer latencies in the higher classes (i.e., Classes 5–7). The latency pattern in the FIT was the same for the gifted and mainstream groups.

Analysis of latencies for correct responses yielded similar results. There were no differences between gifted and mainstream groups. Latencies did not differ as a function of age for Classes 2 to 5, but older children had longer latencies in Classes 6 and 7. In sum, gifted children had shorter latencies in relatively simple, speeded tasks (spatial location, Stroop, and Trail Making tasks), but there was no difference in response time between gifted and mainstream groups on a complex problem-solving task (FIT).

#### *Relationship Between Measures of Speed of Processing and M Capacity*

Some researchers have proposed that differences in processing capacity can be explained in large part by developmental and individual differences in speed of processing (e.g., Kail & Salthouse, 1994; Kranzler et al., 1994). We examined the extent to which performance on the *M*-capacity measures could be accounted for by latency scores. Table 3 contains Pearson correlations between the *M*-capacity tasks and latency in the simplest condition in each speeded task (i.e., response to the prime

Table 3  
Correlations Between *M* Measures and Latencies on Speeded Tasks, for Combined Gifted and Mainstream Samples

	CSVI-M	FIT-M	FIT time	Prime	Neutral	Trail A
1. Age	.43**	.50**	.31**	-.54**	-.59**	-.37**
2. CSVI-M		.59** (.49**)	.33** (.22**)	-.52** (-.39**)	-.38** (-.18*)	-.35** (-.23*)
3. FIT-M			.38** (.26**)	-.53** (-.36**)	-.37** (-.09)	-.40** (-.24**)
4. FIT time				-.32** (-.19*)	-.27** (-.12)	-.14 (-.02)
5. Prime					.57** (.37**)	.40** (.27**)
6. Neutral						.50** (.37**)

Note: Numbers in parentheses are correlations with the effect of age removed. FIT-M = figural intersections task mental-attentional (*M*) score; CSVI-M = compound stimuli visual information *M* score; FIT time = mean latency in Item Classes 5 to 7; prime = median response time to prime stimuli in the spatial location task; neutral = mean latency in neutral condition of the Stroop task; Trail A = mean latency in Trail Making Test Part A.  $N = 141 - 149$ .

\* $p < .05$ . \*\* $p < .01$ .

stimulus in the spatial location task, the neutral condition for the Stroop task, and Trail Part A), across ages for the combined gifted and mainstream samples. Latency for the FIT was averaged across Item Classes 5 to 7 to reflect processing time in complex (*M*-demanding) items. Latencies in the lower classes (corresponding to processing time in simpler items) did not correlate with other measures, possibly because times were fairly fast and variance was low. Latency in the higher classes of the FIT correlated positively with age and with performance on both *M* measures (FIT and CSVI). In contrast, latency in the speeded tasks correlated negatively with age and *M*-capacity scores. Latency in the spatial location task was more strongly related to FIT and CSVI performance than were the other speeded measures. Correlations between *M* measures and latency scores were reduced when the effect of age was removed, but they remained significantly different from zero for all except the Stroop task. Thus, latency on speeded tasks predicted performance, to some extent, on the *M* measures, and this was particularly true for the prime condition of the spatial location task—a fairly simple choice RT measure. We performed a series of Group  $\times$  Age analysis of covariance (ANCOVA) to determine whether latency on the speeded tasks could in fact account for group or age differences on the *M* measures.

For each of the FIT-M and CSVI-M scores we first covaried response time to the prime stimulus; then prime and Trail A latencies; then prime, Trail A, and neutral latencies. In each case, the age and group effects remained significant for the FIT-M score. For the CSVI, covarying latency eliminated the age effect, but the significant group effect was maintained. Thus, the gifted advantage on the *M* measures cannot be explained in terms of greater speed of processing.

#### Relationships Between Measures of Inhibition and *M* Capacity

We examined correlations between measures of inhibition. We expected to find correlations between measures requiring effortful inhibition but not necessarily between measures of effortful versus automatic inhibition. We also examined the extent to which age and group differences on *M*-capacity measures could be accounted for by measures of inhibition. Some researchers have proposed that differences in processing capacity can be explained largely in terms of inhibitory processes (e.g., Bjorklund & Harnishfeger, 1990; Harnishfeger & Bjorklund, 1993, 1994).

Pearson product moment correlations were computed for selected scores from the inhibition measures, for the total sample, with and without the effect of age (see Table 4). To not confound indexes of inhibition and susceptibility to interference with overall differences in response time, we used the transformed difference scores, described earlier. The resulting spatial NP and Stroop NP scores should index efficiency of automatic and effortful inhibition, respectively. The Stroop effect and Trail B scores should reflect susceptibility to interference in tasks requiring mental effort.

There was no correlation between the two measures of NP (spatial and Stroop NP). This is consistent with our claim that the two tasks tap different kinds of inhibition (automatic vs. effortful). Contrary to expectation, the two measures of susceptibility to interference (Stroop effect and Trail B) did not correlate with each other. Moreover, Trail B did not correlate with the score we considered to index effortful inhibition (Stroop NP). There was, however, a negative correlation, as expected, between Stroop NP and the magnitude of the Stroop

Table 4  
Correlations Between *M* Measures and Transformed Inhibition Measures for Combined Gifted and Mainstream Samples

	Spatial NP	Stroop NP	Stroop effect	Trail B
Age	-.08	.17*	-.27**	-.19*
CSVI- <i>M</i>	-.07 (-.04)	.02 (-.06)	-.24** (-.15)	-.15 (-.09)
FIT- <i>M</i>	.01 (.05)	.09 (-.01)	-.19* (-.08)	-.11 (-.01)
FIT time	.09 (.13)	.05 (.02)	-.08 (.00)	.01 (.08)
Spatial NP		-.01 (.00)	.02 (.02)	.14 (.14)
Stroop NP			-.29** (-.26**)	.02 (.05)
Stroop effect				.15 (.11)

Note: FIT-*M* = figural intersections task mental-attentional (*M*) score; CSVI-*M* = compound stimuli visual information *M* score; FIT time = mean latency in Item Classes 5 to 7.  $N = 141 - 147$ . Numbers in parentheses are correlations with the effect of age removed. RT (reaction time) in the following formulas refers to latency. Spatial NP = ((mean of C+L+ and C-L+ RT) - baseline C-L-)/C-L-. Stroop NP = (IR RT - Stroop RT)/Stroop RT. Stroop effect = (Stroop RT - neutral RT)/neutral RT. Trail B = (Trail B - Trail A)/Trail A. \* $p < .05$ . \*\* $p < .01$ .

effect: Efficient inhibition in the task (NP) was associated with reduced Stroop interference.

The two *M* measures correlated negatively with the Stroop measure of susceptibility to interference, suggesting that interference proneness may be a liability in the *M* tasks. These correlations became statistically nonsignificant, however, when age was partialled out.

Finally, we used ANCOVA to determine whether differences in the transformed Stroop score could account for age and group differences on the *M* measures. This was not so: Age and group effects remained significant for FIT-*M* and CSVI-*M*.

### Discussion

Gifted children often outperform their mainstream peers on measures of cognitive functioning, and these advanced abilities have been attributed to faster rates of information processing or to more efficient inhibitory processes (Alexander et al., 1995; Coyle, Read, Gaultney, & Bjorklund, 1998; Harnishfeger & Bjorklund, 1994; Kranzler et al., 1994; Saccuzzo et al., 1994). As hypothesized, we found that gifted children responded more quickly than their mainstream peers on speeded tasks that ranged from choice RT (spatial location task), to color naming (Stroop task), to interleaving of numeric and alphabetic sequences (Trail Making Test). Also, consistent with prediction, we found that gifted children were better able to resist interference in tasks that required effortful inhibition (Stroop effect and Trail Making Test). This result was obtained when task latencies were examined. Analysis of transformed scores (which controlled for differences in speed in the control condition of each task) suggested, however, that reduced Stroop interfer-

ence might be due to greater speed in basic color naming rather than to superior inhibitory ability in gifted children. In contrast, speed in number sequencing did not account for reduced interference for gifted children in the Trail Making Test. Speed in Part B of the Trail Making Test requires fairly sophisticated control of mental attention (inhibition and activation processes), and it may be that gifted children excel in control of attention rather than in efficiency of inhibition, per se.

The NP tasks showed a different pattern from the tasks that tapped proneness to interference. Gifted children showed equivalent NP to mainstream children on both NP tasks. Gifted children may be quicker to apply their attentional resources to tasks; however, NP may reflect the residual effect of the magnitude of inhibition (attentional interruption) that was applied. Our results suggest that this magnitude may not differ between gifted and mainstream children.

The speeded tasks in the present study were not the simple elementary cognitive tasks often used in the intelligence literature (e.g., Kranzler et al., 1994). Latencies, even in the control conditions in the present study, reflected more or less complex cognitive processes plus motor processes. These tasks were not, however, unlike the speeded tasks often used in the developmental literature (e.g., Kail, 1988, 1991).

As predicted, gifted children scored higher than mainstream children on the *M*-capacity tasks—measures of the power of their effortful activation processes. This is consistent with findings that gifted children often excel on working-memory-span measures (e.g., Saccuzzo et al., 1994; Schofield & Ashman, 1987; Segalowitz et al., 1992) and that working memory is highly related to the general

factor of intelligence in adults (e.g., Engle et al., 1999; Kyllonen, 2002). The mean *M*-capacity scores for the mainstream children were in line with theoretical predictions based on the children's ages. The gifted groups, however, scored about one stage (i.e., 1 or 2 years) above their age-predicted levels. Covarying latencies in the speeded tasks did not eliminate the gifted advantage on either of the *M* measures. Likewise, covarying a measure of inhibition failed to eliminate group differences on the *M* measures. Response time patterns on the FIT—a complex problem-solving task—were similar for gifted and mainstream samples. This is consistent with the claim that gifted children may strategically moderate their speed of responding to suit the demands of the task (e.g., Reams et al., 1990; Sternberg & Davidson, 1982), suggesting a superior executive know-how.

The gifted advantage on the *M*-capacity measures, thus, is not due to greater speed in basic processing or to superior inhibitory ability. Does it reflect enhanced capacity, or can it be explained in terms of superior executive strategies? The current set of data does not allow us to decide between these two possibilities. The research literature suggests that gifted children have superior executive abilities: For example, they quickly develop problem-solving strategies and are flexible in their strategy use (e.g., Coyle et al., 1998; Gaultney, Bjorklund, & Goldstein, 1996; Shore, 2000). Other data suggest that gifted children may more readily apply strategies that can reduce the capacity demand of FIT items (Bauer, 2003). However, Gaultney et al. (1996) and Harnishfeger and Bjorklund (1990) found that gifted children showed an advantage in a free-recall task that could not be explained in terms of strategic processes alone. Furthermore, in the present study, the latency pattern on the FIT was identical for gifted and mainstream children (see Figure 6), suggesting that the two groups may have been using similar strategies and persisting in problem solution to the same degree. Thus, at least some gifted children may be advanced in both capacity and executive processing.

Patterns of age differences were largely consistent with predictions. Consistent with past research (e.g., Kail, 1988, 1991), older children were faster than younger children on the speeded tasks. Older children were better able to control interference on the Stroop task and Trail Making Test. Analysis of transformed scores suggested that speed of processing might account for the age differential on the Trail Making Test but not for increased Stroop interference in the younger children. Young and older children showed equivalent NP on the spatial location NP task. This is congruent with previous

research (Simone & McCormick, 1999; Tipper & McLaren, 1990) and suggests that automatic inhibition may be well established by the early school years. Also consistent with previous research (Tipper et al., 1989; Visser, Das-Smaal, & Kwakman, 1996), NP in the Stroop task was shown only by older children, suggesting that effortful inhibition may have a longer developmental course.

As expected, older children scored higher than younger children on *M*-capacity measures. Covarying speed removed the age effect for the CSVI-*M* score but not for the FIT-*M* score. Although children were not instructed to respond quickly on the CSVI, speed may have provided some advantage, because the stimulus card was displayed for only 6 s. There was a small negative correlation between Stroop interference score and each of the *M* measures; however, these correlations became statistically nonsignificant when age was partialled out. Covarying the transformed Stroop interference score did not eliminate the age effect for either *M*-capacity measure.

Support for the distinction between automatic and effortful inhibition was mixed. As noted earlier, group and age differences were restricted to tasks that required effortful inhibition, as predicted. As expected, the measure of automatic inhibition did not correlate with the measures of effortful inhibition. However, contrary to prediction, measures of effortful inhibition also failed to intercorrelate. This is consistent with Dempster's (1993) proposal that inhibition is a family of specialized inhibitory processes, each operating under certain circumstances and under different task demands (see also Nigg, 2000). The only correlation significantly different from zero was within a single task—the Stroop-interference and NP scores from the Stroop task. This suggests that efficiency of inhibition may be negatively related to degree of experienced interference within a type of task. However, it appears to be difficult to measure inhibition as a stable ability, and researchers need to be aware of task demands and type of inhibition required when selecting measures of inhibitory processes. Few studies have examined associations between different measures of inhibition. Carlson and Moses (2001) reported moderate correlations among 10 tasks thought to measure inhibitory control in preschoolers. However, other researchers studying older children or adults have failed to find correlations between measures of inhibition derived from different tasks (e.g., Band, van der Molen, Overtoom, & Verbaten, 2000; Kramer, Humphrey, Larish, Logan, & Strayer, 1994; Shilling, Chetwynd, & Rabbitt, 2002). Johnson et al. (2003) have obtained correlational data

with adults supporting the distinction between automatic and effortful inhibition; however, the current results raise the question of whether these two types of inhibition can be easily separated empirically.

Although both inhibition and speed of processing have been proposed to have a primary role in determining cognitive capacity, there was no evidence to suggest that efficiency of inhibition or speed of processing might explain the gifted advantage on measures of *M* capacity. This negative result is consistent with our claim that mental attention, in gifted as well as mainstream children, has distinct inhibition and activation mechanisms that interact in producing cognitive performance (Pascual-Leone, 1987, 1995, 2000; Pascual-Leone, Johnson, Baskind, et al., 2000). This is also consistent with Band et al.'s (2000) finding of different developmental trajectories for speed of response activation and speed of response inhibition.

Finally, one might ask what the results tell us about gifted cognition. Analyses consistently yielded main effects for group and age, but no interactions between group and age. For the most part, young gifted children performed at similar levels to older mainstream children, suggesting that gifted children were developmentally advanced in the processes tested here. This was the case in the *M*-capacity measures, overall latencies in the speeded tasks, and measures of resistance to interference. There were a few exceptions to this pattern, however, when gifted children performed more like their mainstream peers. In the spatial location task, gifted children experienced NP to the same extent as mainstream children, but young children in both groups experienced enhanced NP when the target matched the previous distractor in both location and color. Older participants were sensitive only to the location match. In the Stroop task, neither of the young groups exhibited NP, but both older groups did (and to the same degree). The latency pattern on the FIT was distinguished in terms of item class and age but not in terms of giftedness. Young children in both groups began to spend less time on task solution at Item Class 5, which was two units beyond their age-predicted capacity. Older children, in contrast, continued to persist in the higher item classes.

This pattern of results is consistent with our theoretical view that the group variable is mainly expressing children's executive know-how, and the age variable is expressing a trade-off (difference) between the children's *M* capacity and the *M* demand of the tasks. The spatial location task has low demand, and here we found no age difference in

degree of NP. The Stroop is a task with relatively higher *M* demand and executive demand, and here we found negative NP only for older children. Consistent with this view are the latency data for the FIT, a task that is graded in *M* demand. Differences related to age were found in the higher item classes but not in the lower classes, irrespective of group.

For the most part, the effect sizes for age were larger than those for group (see Table 2). The major exception was for the Trail Making Test, in which the group effect was higher. Again, this suggests that gifted children may excel in control of attention when inhibition and activation processes must be coordinated (consistent with Engle et al.'s, 1999, view of the relationship between controlled attention and *g*). At the same time, the generally larger effect sizes for age may be a function of the age range tested and the complexity levels of the tasks. Research with older age groups, for example, might yield a different pattern of effect sizes.

In sum, the present results suggest that gifted children perform at an advanced level on measures of *M* capacity, speed of processing, and ability to control effortfully interference. They do not appear, however, to be developmentally advanced in inhibition as measured by the NP paradigm. We see mental attention as a functional system constituted by brain resources for activation of relevant schemes and inhibition of irrelevant schemes, along with executive processes for controlling (mobilizing and allocating) these resources (Pascual-Leone, 1987, 1995, 2000). Most likely, gifted children excel at executive control of effortful mental-attentional processes, but not in inhibitory ability, per se. The current data leave open the question of whether gifted children have greater resources for holding relevant information active.

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