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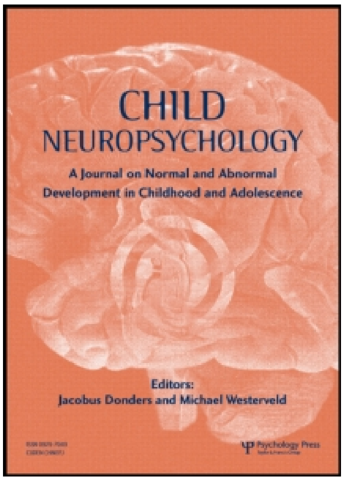

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DEVELOPMENTAL CHANGES IN ATTENTION TESTS NORMS: IMPLICATIONS FOR THE STRUCTURE OF ATTENTION

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Assessment of attention is a key issue in the study of neuropsychological development. In this study we collected Hebrew norms for four frequently used attention tests (Trail Making, Digit-Symbol, Digit Span, and Digit Cancellation), analyzed the developmental sensitivity of each test and traced changes in attention across ages. The tests were administered to 809 boys and girls ranging in age from 8 to 17, divided into 10 age cohorts. The results indicate that, although all tests showed age effects, Digit-Symbol and Digit Cancellation tests were most developmentally sensitive. Another interesting finding was that younger age groups (8–11) are more dissociable by attention tests than older age groups (12–17), indicating that changes in attention are more pronounced in the early years and stabilize in later years.

Keywords: ***Attention; Development; Test; Norms.***

The study of the development of attention occupies a central place in cognitive developmental psychology and developmental neuropsychology. Difficulties in attention and memory may result from a variety of causes (e.g., genetic, pre- and postnatal, and head injuries) and have been associated with academic difficulties, behavior problems, and poor social functioning (DuPaul, McGoey, Eckert, & VanBrackle, 2001). The most common deficits reported following head trauma in children are memory and attention deficits (Frazier, Demaree, & Youngstrom, 2004; Levin, Ewing-Cobbs, & Eisenberg, 1995). Most contemporary theories and models of information processing view attention and memory as two interacting processes (Anderson, Godber, Smibert, Weiskop, & Ekert, 2004). Executive functions, deemed essential to adequate academic and social functioning, also play a major role in attention and memory (Anderson, 1998; Klenberg, Korkman, & Lahti-Nuuttila, 2001).

Theoretical models of attention describe it as a multicomponent process, including functionally separable systems supported by a number of brain regions (Cohen, 1993;

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Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991; Posner & Petersen, 1990). One of the attentional models that allows the classification of various attentional tests according to multiple attentional components is that of Cohen. According to Cohen's model there are four distinguishable components. First, *Sensory-Selective Attention*, which is applied when some stimuli are selected for further information processing while other stimuli are filtered. This component includes selective or focused attention, and automatic processing such as priming and the Orienting Response. Second, *Response Selection and Control* by which selected stimuli may be further processed as determined by task goals, and response production selected from available alternatives. This component controls the initiation or inhibition of an attentional response and active switching between attentional response alternatives. Third, *Attentional Capacity* limits the amount of information that a person can simultaneously process. Fourth, *Sustained Attention* reflects the maintenance of attention over time and is based on the previous factors.

Although other models have used different terms, they represent similar dissociations. For example, Cohen's distinction between sensory selection, response selection, and sustained attention components resembles that of Mirsky et al. (1991), which distinguishes between focus-execute and sustained-attention components, and that of Posner and Petersen (1990) that differentiates orient-detect from maintenance and vigilance components. Furthermore, the components of capacity and switching ability (Cohen, 1993) are parallel to encode and shift elements (Mirsky et al.).

Confirmation of the distinctions between attentional components comes, *inter alia*, from developmental studies. For example, Klenberg et al. (2001) have shown a sequential development of the attention processes: beginning with inhibitory functions (maturing at age 6 to 7; in Cohen's terminology, response control), followed by vigilance (in Cohen's terminology, sustained attention) and selective attention (maturing at the age of 10; in Cohen's terminology, sensory selection), with the last to mature being the executive functions (maturing at the age of 11; in Cohen's terminology, response selection). Several researchers have reported that the most pronounced changes in attention processes, primarily in sustained attention, take place between the ages of 8 to 10 (Betts, Mckay, Maruff, & Anderson, 2006; Rebok et al., 1997). However, Manly et al. (2001) reported improvement in different attention components (i.e., selective, sustained, and executive control) up to the age of 16.

Some of the most frequently used attention tests are composed of two complexity levels (e.g., Trail Making Test: Reitan & Davison, 1974; Digit Cancellation: Diller et al., 1974; Digit Span: Wechsler, 1991). In several factor analysis studies, less complex and more complex components loaded on different factors, indicating different underlying cognitive processes (Trail Making Test: Crowe, 1998; Duff, Schoenberg, Scott, & Adams, 2005; Kortte, Horner, & Windham, 2002; Digit Span: Gathercole, 1999). Based on these studies, it is predicted that the more complex components of these tasks should be more age dependent than the simpler components.

The four tests administered in the present study will be reviewed in the following sections, with special reference to developmental data: the Trail Making Test, Digit Cancellation test, Digit-Symbol test, and the Digit Span test.

***Trail making test (TMT*: Reitan & Davison, 1974).** This test is widely used in neuropsychology and has been defined as a test of visual scanning and tracking, processing speed, focused and divided attention, working memory, cognitive flexibility, and shifting of attention (Lezak, Howieson, & Loring, 2004). Some of these processes are considered components of executive functions (Anderson & Pentland, 1998; Espy & Cwik, 2004; Horton & Roberts, 2003; Lezak et al., 2004). The test consists of two parts: Part A requires the individual to draw lines that connect consecutive digits, printed in a scattered pattern on a page. Part B requires drawing lines that connect sequences of letters and digits, alternatively (i.e., 1-A-2-B and so on). The time to completion of each part and the numbers of errors are recorded. Different errors can be identified on this test: omissions, commissions, perseveration in one set (set-loss), sequencing errors such as a proximity error that may indicate a problem of inhibition on Part A; displacement errors that may indicate a similar problem on Part B. It has been argued that Part A measures visual scanning and tracking, motor speed and focused attention, whereas Part B measures cognitive flexibility and set shifting, and divided attention. As such, it is a more sensitive measure of executive functions (Anderson & Pentland, 1998; Arbuthnott & Frank, 2000). Several studies on adults have supported this distinction (Crowe, 1998; Duff et al., 2005; Kortte et al., 2002). In children, performance on the TMT was correlated with tests of executive functions, such as the Tower of London and the Rey Complex Figure Test (Anderson, 1998). It has also been claimed that the two parts are not equivalent and that Part B is longer and more visually complex, thus demanding more visuospatial processing (Spreen & Strauss, 1998). Indeed, Part B was also found to load on a spatial intelligence — nonverbal ability factor (see Baron, 2004, for review).

Some investigators subtract in adults the Part A score from the Part B score in order to obtain a more pure measure of attention, flexibility, and set-shifting ability, without the speed component (Holtzer, Stern, & Rakitin, 2005; Lezak et al., 2004). Others in children, recommend using the ratio score B/A (number of correct connections in each part or time to completion) as a more valid index (Baron, 2004; but see Martin, Hoffman, & Donders, 2003).

A factor analysis study has found that Part A loaded on a focus/execute factor, together with Digit-Symbol, Cancellation, and the Stroop test (Mirsky et al., 1991). It was classified as a sensory selection factor, together with copying of the Rey Complex Figure, Logical memory, visual search, and the discriminability score of the Continuous Performance Test (CPT: Lockwood et al., 2001). Part B was found to load on a capacity/focus factor (together with Digit-Symbol, Digit Span Backwards, Stroop test, CPT reaction time, and delayed recall of the Rey Complex Figure) (Mirsky et al., 1991); and classified as a response selection factor (together with number of commissions in a Cancellation test and in CPT, category fluency, Controlled Oral Word Association Test (COWA) rule violation, and Wisconsin Card Sorting Test (WCST) set failure; Lockwood et al., 2001), whereas both parts loaded on a speed of response factor (Kelly, 2000), together with cancellation, CPT reaction time, Digit-Symbol, arithmetic, Digit Span, Symbol Search, and the Stroop test.

Norms have been published for different children age groups, ranging from 7–18 years (Baron, 2004; Spreen & Strauss, 1998), 7–13 years (Kelly, 2000), and 9–14 years (Stanczak & Triplett, 2003). In the Hebrew language and culture there is a strong association between digits and letters. For example, days of the week and grades in school are labeled alphabetically, thus possibly creating a closer association between digits and letters than in other languages. A recent study provides evidence that the processing of Hebrew letters is flexible, so that they function as ideographic symbols in an arithmetic context, at least for adults (Razpurker-Apfeld & Koriat, 2006). Therefore, having Hebrew norms on this particular test is very informative.

***Digit cancellation test* (Diller et al., 1974; Lezak, 2004, p. 381).** On this task, participants are required to cross out target digits printed on a page in an organized pattern.

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In the present study, participants are required to scan an organized pattern of digits (by rows, just as in reading) and cross out the digit "8" in the simpler version (Part A) of this test, and "3" and "5" on the more complex version (Part B). Cancellation tests are considered to measure focused and selective attention, speed of information processing, short-term memory, and cognitive flexibility (Anderson et al., 2004; Anderson & Pentland, 1998; Kelly, 2000). Time to completion and number of omissions and commissions are usually measured, and sometimes the organizational quality or strategy of performance is noted.

Performance on Cancellation tests loaded on a focus/execute factor (Mirsky et al., 1991), together with the Digit-Symbol test, TMT Part A, and the Stroop test. In children, Cancellation time loaded on a speed-of-response factor, together with CPT reaction time, coding, arithmetic and digit span, and the number of errors loaded on an impulsivity factor (Kelly, 2000). Number of hits classified as a sustained-attention factor (together with COWA word generation decrement and fluency decrement), and the number of commissions classified as a response selection factor (Lockwood et al., 2001), together with TMT Part B errors, number of commissions in a cancellation test and CPT, COWA rule violations, category fluency, and WCST set failure.

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***Digit-symbol subtest of the Wechsler Adult Intelligence Scale-Revised (WAIS-R)* (Wechsler, 1991).** This is a subtest of the Wechsler Intelligence Tests and taps processing speed, visual tracking and scanning, visual-motor coordination, focused and sustained attention, short-term memory, cognitive flexibility and rapid shifting, and the ability to learn a new task (Anderson & Pentland, 1998; Kinsella, 1998; Sattler, 1992). In adults, perceptual and graphomotor speed and visual scanning efficiency have been found to contribute substantially to the variance of this test (Joy, Fein, & Kaplan, 2003); whereas memory has been found to make a modest contribution (Joy, Kaplan, & Fein, 2004). Women outperform men on the Digit-Symbol Test, at least in the 20–44 years age range, and performance is mediated by educational level (Jorm, Anstey, Christensen, & Rodgers, 2004). Digit-Symbol loaded in children on a speed of response factor, together with CPT reaction time, cancellation, arithmetic and digit span (Kelly, 2000). In adults, it was loaded on a focus/execute factor, together with TMT Part A, cancellation test, and the Stroop test (Mirsky et al., 1991), and classified in children, as capacity/focus factor (Lockwood et al., 2001), together with Digit-Span Backward series, the Stroop test, reaction time on the CPT, TMT Part B, and delayed recall of the Rey Complex Figure.

***Digit span subtest of the WAIS-R* (Wechsler, 1991).** This test measures auditory attention and short-term memory (Sattler, 1992). It has two parts: The Digits Forward sequence (starting from three digits and increasing on each trial by one digit, up to nine digits) requires the individual to immediately repeat sequences of orally presented digits in the same order as presented; the Digits Backward sequence (starting from two and increasing by one digit up to eight digits) requires the immediate repetition of the digits in reverse order. There are two series of digits for each sequence length.

The Forward part requires more simple attention and mental tracking and, presumably, measures the store component of working memory or attention (Kinsella, 1998; Price, Joschko, & Kerns, 2003). Using Baddeley's (1986) working memory model, Gathercole (1999) suggests that while the Digits Forward task reflects the processing in the phonological loop, the Backward part relies more on the central executive component of working memory. Similarly, other researchers emphasized the contribution of mental

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effort, retention, and mental manipulation, and it is therefore a more sensitive measure of flexibility, concentration, and frustration tolerance (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Kinsella, 1998; Lamar, Zonderman, & Resnick, 2002; Sattler, 1992).

Developmental norms, combined for both forward and backward series, are reported in the Wechsler Intelligence Test Manual but were also published separately for each series by Anderson et al. (2001) and Sattler (1992). Measures used in this test include: sum of the forward and backward series, the longest sequence correctly recalled for each series, or sum of all trials for each series. Men outperform women on the Digits Backwards Series in the 20–64 years age range, and performance is mediated by educational level (Jorm et al., 2004). Regarding children, Anderson et al. (2001) reported significant improvements on the Digits Forward series and found that 15-year-olds performed better than 11- to 14-year-olds. On the Digits Backward series, no age difference was found. However, in the 11-year-old group, girls performed more poorly than boys, and this pattern was reversed in the 12–15+ year-old groups, where girls outperformed the boys.

Total Digit Span score loaded in children on a speed of response factor, together with CPT reaction time, Digit-Symbol, arithmetic and cancellation (Kelly, 2000), and on an encoding factor, together with arithmetic (Mirsky et al., 2001). The forward series was classified as a sensory selection factor, together with copying of the Rey Complex Figure, TMT Part A, story memory, visual search and the discriminability score of the CPT; the Backward series classified on a capacity/focus factor (Lockwood et al., 2001), together with Digit-Symbol test, Stroop test, reaction time of the CPT, TMT Part B, and delayed recall of the Rey Complex Figure.

Thus, these four tests are frequently used individually or as part of a battery to measure different aspects of attention. Furthermore, three of these tests are also composed of two complexity levels. According to Cohen's (1993) theoretical framework, these tests reflect different attentional components: TMT reflects Response Selection, Digit Span reflects Attentional Capacity, and Cancellation and Digit-Symbol reflect Sustained Attention. Different developmental time lines for performance on these four tests would further validate the attention components distinctions and would indicate the sequence in which the different components reach maturation.

The purpose of the present study is threefold: first, to collect and to present developmental norms on the aforementioned attention tests for a large sample of Hebrew-speaking children and adolescents; second, to analyze the sensitivity of each test to developmental processes; and third, to trace developmental changes in attention across ages, and to assess whether changes are more pronounced in some age transitions than with others, across the age range tested (i.e., 8–17). These findings have the potential to make a significant clinical and theoretical contribution.

METHODS

Participants

The attention tests used in this study were administered at the same time as the collection of Hebrew norms on the Rey Auditory-Verbal Learning Test (AVLT: Vakil, Blachstein, & Sheinman, 1998). Eight hundred and nine children (416 boys and 393 girls) participated in this study. The age range of the sample population was from 8 to 17 years, divided into 10 age cohorts. The children's sample for the study was recruited from a population of children in 14 public schools in central Israel (i.e., the greater Tel Aviv area). The Israeli Ministry of Education uses a scale by which all public schools in the country are ranked according to five criteria: parents' income, parents' education, family size, proportion of immigrants in the school, and distance from a major city. We were referred to public schools ranked in the middle range of this scale. After receiving approval from the school's principal, the class teacher was approached. The teacher or the principal was asked *not* to refer children with either very high or very low academic achievement to the study. Based on the teacher's judgment, children with learning disabilities, attention disorders, or those requiring special assistance in school were also excluded. All the children were selected according to their birth dates, so that only those children whose birthdays fell within the three months prior to or after the testing date were tested. All participants were born in Israel, and Hebrew was their primary language. Ten to 20 children participated from each school in each class year, which were sampled from different parallel classes of the same grade. The sample for each school year was drawn from four to six schools. An additional 124 children (63 boys and 61 girls) in the same age groups from different parts of the country were tested on a voluntary basis, fulfilling the same selection criteria as the former group. Based on a preliminary analysis, since this group did not differ from the rest of the sample on any parameter, the two samples were merged.

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Tests and Procedure

Children were tested individually in a room allocated for this purpose, in their own schools, and during school hours. The children participated voluntarily in the study. Furthermore, they were told that they could stop at any time if they wished to do so. This happened with just a few children who claimed that they were tired. In addition to the Digit-Symbol, Digit Span, Cancellation and the Trail Making Tests, the children were tested on the Rey AVLT and the vocabulary subtest of the Wechsler Adult Intelligence Scale-Revised (WISC-R). Some of the tests were administered during the 20-minute delay in administration of the Rey AVLT, and the remainder following the Rey AVLT. The examiners in this project were 14 undergraduate psychology majors at Bar-Ilan University, who were trained to administer and to score the tests.

Trail making test. Administration was according to Lezak (1995). The adult version was administered to all age groups in order to enable comparison across age groups on the same test. The difference between the children's and the adults' versions is in the number of circles (15 vs. 25, respectively). In the dual task (Form B), the correct trail alternates between 13 number targets and 12 letter targets. In this study, following the standard Hebrew practice, the last two letter targets are the Hebrew letter combinations *yod-alef* and *yod-bet*, which bear numerical values of 11 and 12, respectively. The digits-only part (Form A) was administered first, followed by the dual task (Form B). Children were instructed to work as quickly and accurately as possible without lifting the pencil. The time to completion of each form was recorded, as were the errors (omissions, wrong sequence, and set-loss). When an error was made, it was pointed out to the participant, who was asked to correct the error.

Digit cancellation test. The test was administered in two stages, in each of which participants were presented with an identical form. The form consists of 312 digits

(3 mm size each) printed in random order and organized in 6 rows and 52 columns. A $1^{1}/_{2}$-cm horizontal space in the middle splits the six rows in two. The digits were printed on an A4 paper in a horizontal layout. Figure 1 displays the form used in the present study. In the first stage participants were given a pencil and were asked to use it to cross out all the "8" digits on the form as fast and as accurately as possible. They were instructed to start with the top row, proceeding from left to right. Upon completion, they were presented with another form and were then asked to cross out all the "3" and "5"digits on the form as fast and as accurately as possible. The time to completion together with omissions and commissions errors were recorded.

Digit-symbol test. Administration was according to the WISC-R (Wechsler, 1974) protocol, which is the version in current clinical use for Hebrew speakers in Israel. The form consists of 4 rows of 25 empty boxes in each, where the first 7 boxes were used for a demonstration and practice trial. Participants were instructed to work as quickly as possible, using a pencil, and going from one box to the next from left to right. On the first skipping error, participants were immediately warned; further errors were noted by the examiner but the participants were no longer warned. The number of correct symbols copied within 120 seconds was recorded in this test.

Digit span test. Administration was according to the WISC-R (Wechsler, 1974) protocol. This task consists of two subtests; digits forward and digits backwards. Digits were read aloud, one digit per second, and responses were noted. There were two sequences for each length, and then the following longer sequence was read. Each sequence was read only once. The digits forward subtest was administered first, followed by the digits backward subtest. Practice trials were always presented, as required by the WISC-R protocol, and if failed, a demonstration and careful explanation followed. The score for each series is the longest sequence correctly recalled.

RESULTS

The effects of age (10 age groups) and gender were analyzed as between-subjects factors in all four attention tests administered. With the exception of the Digit-Symbol task, all the other tasks consist of two subtests; the first assessing baseline performance and the second being the more complex and more demanding subtest. The comparison of the two subtests (complexity factor) was analyzed as a within-subject factor. Thus, a mixed-design ANOVA was used to analyze the two between-subjects factors and the within-subject factor

2 8 4 6 3 8 3 6 8 7 9 8 3 8 9 8 2 4 1 8 3 6 2 8 4 5 8 4 1 6 8 9 3 8 6 8 2 1 6 8 5 8 6 8 3 2 4 8 6 7 8 5
8 5 7 8 6 5 8 4 8 6 8 3 2 6 8 1 4 8 3 5 8 9 8 7 4 8 7 5 2 8 5 7 8 9 8 3 8 5 8 6 3 9 8 5 2 8 7 6 4 8 2 5
8 2 8 1 5 8 2 8 3 6 1 8 6 8 7 8 3 7 4 8 3 2 1 8 7 4 5 8 3 8 2 5 8 4 7 8 4 1 6 8 2 9 6 8 5 2 8 4 8 5 8 7

8 4 7 1 8 3 8 6 2 8 1 6 8 5 2 6 8 3 4 8 6 8 7 5 8 2 8 1 8 6 1 3 8 3 8 6 4 9 8 3 2 9 8 2 8 1 3 8 4 8 6 2
5 8 2 8 7 2 9 8 3 5 8 1 6 8 9 8 5 2 8 7 6 2 8 6 1 8 5 2 7 8 7 6 5 8 4 2 8 2 8 3 6 8 1 4 3 9 5 9 8 6 8 7
8 4 3 2 8 5 4 7 8 1 4 6 8 2 8 9 7 5 8 7 8 4 5 8 3 7 8 4 8 5 2 1 8 6 2 8 3 4 1 8 7 2 8 3 8 4 6 8 3 1 9 8

Figure 1 Digit Cancellation test.

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for the three tests. For the Digit-Symbol task, only the between-subject factors (age and gender) were analyzed. Due to the multiplicity of statistical analyses conducted, $p < .01$ was used as the criterion for significance in order to reduce the probability of type I error.

***Trail making test* (TMT).** Time to completion and number of errors on TMT were analyzed. Tables 1a and 1b present the mean and *SD* of the boys and girls, respectively, on the different measures of the TMT for the 10 age groups.

Time to Completion. The time to completion was significantly reduced with age, $F(9, 778) = 107.22$, $p < .001$, $\eta^2 = .55$. The most significant changes took place in the younger age groups (i.e., 8–11). The Complexity effect (Part A [digits only] versus Part B [digits and letters]), reached significance as well, $F(1, 778) = 2538.84$, $p < .001$, $\eta^2 = .77$. Time to completion of Part A was faster (37.00 ± 17.71) than for Part B (91.29 ± 48.80). The interaction of Complexity × Age reached significance as well, $F(9, 778) = 49.48$, $p < .001$, $\eta^2 = .36$. As can be seen in Tables 1a and 1b, this interaction is due to the fact that the changes as a function of age (particularly in the younger age group, 8–12 years) in Part B are steeper than the changes in Part A. In order to detect the source of the interaction, a one-way ANOVA was conducted on the difference score of the two parts of the test (Part B – Part A). This analysis yielded a significant age group effect $F(9, 788) = 49.58$, $p < .001$. Post hoc comparisons using the Scheffe test indicated that the difference score (see Table 5) is more significant in the younger age groups (i.e., 8–12) than in the older age groups (i.e., 13–17). The main effect of Gender, the Age × Gender interaction, and the three-way interaction did not reach significance.

Number of errors. Overall, younger children made more errors than the older ones, $F(1, 784) = 3.42$, $p < .001$, $\eta^2 = .04$ and more errors were made in Part B compared to Part A, $F(1, 784)=166.71$, $p < .001$, $\eta^2 = .18$. The significant interaction between these two factors, $F(9, 784) = 4.28$, $p < .001$, $\eta^2 = .05$, is due to the fact that while errors do not change significantly over the age groups in Part A, they do decrease over the years in Part B. Gender effect and all the other interactions did not reach significance. The main effect of Gender did not reach significance, however the Gender × Age interaction was significant, $F(9, 784) = 2.75$, $p < .01$, $\eta^2 = .03$, due to an alternation of superiority between boys and girls across the ages. None of the other interactions were significant.

Digit cancellation test. Time to completion and number of errors were analyzed. Tables 2a and 2b present the mean and *SD* of the boys and girls, respectively, on the different measures of the Digit Cancellation test for the 10 age groups.

Time to completion. The three main effects reached significance. The time to completion was significantly reduced with age, $F(9, 778) = 190.93$, $p < .001$, $\eta^2 = .69$. The Complexity main effect, $F(1, 778) = 1010.33$, $p < .001$, $\eta^2 = .57$, indicates that overall completion of the one-digit task was faster than the two-digit task (99.23 ± 33.0 and 127.30 ± 52.65, respectively). The significant Gender effect, $F(1, 778) = 14.30$, $p < .001$, $\eta^2 = .02$, reflects the fact that boys (116.91 ± 1.14) are slower than girls (110.73 ± 1.17). The Complexity × Age interaction reached significance as well, $F(9, 778) = 35.9$, $p < .001$, $\eta^2 = .29$. In order to detect the source of the interaction, a one-way ANOVA was conducted on the difference score of the two parts of the test (two-digits minus one-digit cancellation). This analysis yielded a significant Age effect, $F(9, 788) = 36.36$, $p < .001$. Post hoc comparisons using

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Table 1 Means and (*SD*) of TMT Scores for Each Age Group, by Gender.

		Age group (years)									
		8	9	10	11	12	13	14	15	16	17
Boys		(*n* = 37)	(*n* = 37)	(*n* = 41)	(*n* = 38)	(*n* = 42)	(*n* = 41)	(*n* = 37)	(*n* = 59)	(*n* = 46)	(*n* = 35)
Part A	Time	59.53	45.16	49.27	38.26	32.86	32.76	29.68	28.26	25.83	25.49
(Digits)	(seconds)	(17.93)	(16.34)	(19.16)	(11.45)	(14.12)	(10.89)	(11.49)	(9.65)	(8.56)	(9.64)
	Errors	0.08	0.08	0.39	0.08	0.17	0.27	0.19	0.10	0.15	0.06
		(0.27)	(0.27)	(0.59)	(0.36)	(0.38)	(0.45)	(0.40)	(0.36)	(0.42)	(0.24)
Part B	Time	161.10	127.95	117.80	98.37	79.43	68.54	70.11	65.12	59.96	53.59
(Dual Task)	(seconds)	(61.28)	(43.50)	(44.81)	(28.76)	(33.51)	(23.01)	(29.69)	(29.75)	(21.90)	(14.86)
	Errors	0.82	0.78	0.88	0.47	0.55	0.32	0.62	0.39	0.48	0.26
		(1.17)	(0.89)	(1.00)	(0.86)	(0.77)	(0.61)	(1.06)	(0.74)	(0.75)	(0.57)
Part B minus	Time	95.97	82.78	68.54	60.10	46.57	35.78	40.43	36.42	34.13	28.53
Part A	(seconds)	(44.67)	(39.95)	(40.41)	(27.84)	(27.57)	(21.10)	(31.81)	(26.41)	(18.08)	(12.61)
Part B minus	Errors	0.74	0.70	0.49	0.39	0.38	0.49	0.43	0.29	0.33	0.21
Part A		(1.25)	(0.99)	(1.00)	(0.95)	(0.88)	(0.80)	(1.14)	(0.83)	(0.87)	(0.48)
Girls		(*n* = 41)	(*n* = 38)	(*n* = 42)	(*n* = 37)	(*n* = 38)	(*n* = 40)	(*n* = 43)	(*n* = 41)	(*n* = 38)	(*n* = 35)
Part A	Time	67.66	51.87	45.07	35.92	32.21	31.63	28.49	28.76	27.88	26.94
(Digits)	(seconds)	(22.40)	(14.86)	(14.10)	(14.15)	(9.20)	(9.59)	(11.23)	(13.12)	(11.09)	(11.18)
	Errors	0.15	0.11	0.05	0.05	0.18	0.13	0.19	0.29	0.05	0.20
		(0.42)	(0.39)	(0.22)	(0.23)	(0.46)	(0.33)	(0.39)	(0.68)	(0.23)	(0.47)
Part B	Time	171.95	148.70	113.00	82.05	79.76	80.15	70.24	64.41	62.84	59.62
(Dual Task)	(seconds)	(47.47)	(47.62)	(36.65)	(22.10)	(33.64)	(33.03)	(26.88)	(25.44)	(24.72)	(21.72)
	Errors	0.70	1.16	0.48	0.47	0.68	0.60	0.38	0.54	0.27	0.29
		(0.88)	(1.51)	(0.67)	(0.86)	(0.81)	(0.93)	(0.62)	(0.98)	(0.61)	(0.57)
Part B minus	Time	104.29	97.43	67.93	46.13	47.55	48.53	41.93	35.66	35.03	32.57
Part A	(seconds)	(44.40)	(41.60)	(33.17)	(18.71)	(30.37)	(31.32)	(24.33)	(23.03)	(20.36)	(18.99)
Part B minus	Errors	0.55	1.05	0.43	0.49	0.50	0.47	0.26	0.24	0.22	0.09
Part A		(0.90)	(1.03)	(0.67)	(0.84)	(1.01)	(0.99)	(0.70)	(1.09)	(0.63)	(0.70)

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Table 2 Means and (*SD*) of Cancellation Scores for Each Age Group, by Gender.

		Age group (years)									
		8	9	10	11	12	13	14	15	16	17
Boys		(n = 39)	(n = 37)	(n = 41)	(n = 38)	(n = 42)	(n = 41)	(n = 37)	(n = 59)	(n = 46)	(n = 35)
Single	Time	155.03	131.14	125.41	108.58	94.79	91.88	85.19	83.88	71.85	69.51
Target	(seconds)	(27.84)	(24.29)	(25.90)	(18.38)	(19.28)	(23.93)	(23.49)	(16.57)	(12.65)	(10.50)
	Commissions	0.00	0.03	0.00	0.00	0.00	0.02	0.03	0.14	0.02	0.09
		(0.00)	(0.16)	(0.00)	(0.00)	(0.00)	(0.16)	(0.16)	(0.47)	(0.15)	(0.37)
	Omissions	2.10	1.11	0.59	1.00	0.81	0.83	1.08	1.51	0.61	0.74
		(3.45)	(1.81)	(0.87)	(1.93)	(1.25)	(1.51)	(1.83)	(1.92)	(0.95)	(1.31)
Two	Time	218.05	180.41	166.34	148.92	125.74	113.66	110.00	89.66	85.52	83.63
Targets	(seconds)	(50.57)	(46.08)	(35.68)	(35.32)	(28.60)	(31.01)	(25.36)	(21.51)	(16.39)	(12.93)
	Commissions	0.13	0.05	0.02	0.08	0.02	0.07	0.14	0.08	0.00	0.03
		(0.47)	(0.23)	(0.16)	(0.36)	(0.15)	(0.26)	(0.54)	(0.28)	(0.00)	(0.17)
	Omissions	3.97	2.86	3.71	2.74	2.52	1.90	1.78	1.59	2.04	2.23
		(3.46)	(2.08)	(3.94)	(2.14)	(2.12)	(2.18)	(2.56)	(1.77)	(2.32)	(2.64)
Two Targets	Time	64.0	49.3	40.9	40.3	30.9	21.8	24.8	5.8	13.7	14.1
minus Single	(seconds)	(39.0)	(29.3)	(24.0)	(24.4)	(20.7)	(34.5)	(25.2)	(22.2)	(14.8)	(12.6)
Target	Omissions	1.87	1.76	2.73	1.74	1.71	1.07	0.70	0.08	1.43	1.48
		(3.85)	(2.47)	(3.23)	(2.39)	(2.52)	(2.64)	(2.86)	(2.93)	(2.66)	(2.91)

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Girls		(n = 41)	(n = 38)	(n = 42)	(n = 37)	(n = 38)	(n = 40)	(n = 43)	(n = 41)	(n = 38)	(n = 35)
Single	Time	154.03	133.11	116.62	95.08	87.39	85.82	81.23	78.90	73.00	67.77
Target	(seconds)	(30.41)	(25.60)	(27.02)	(15.49)	(15.93)	(15.92)	(18.43)	(17.09)	(14.90)	(9.83)
	Commissions	0.05	0.00	0.10	0.08	0.00	0.05	0.02	0.02	0.00	0.00
		(0.22)	(0.00)	(0.37)	(0.28)	(0.00)	(0.22)	(0.15)	(0.16)	(0.00)	(0.00)
	Omissions	1.90	1.34	1.79	0.68	1.39	0.70	0.53	1.73	0.83	0.71
		(2.69)	(1.73)	(3.89)	(1.25)	(2.17)	(1.87)	(0.91)	(2.64)	(1.18)	(1.43)
Two	Time	213.68	180.79	155.79	126.78	113.32	108.38	93.65	84.54	88.08	80.17
Targets	(seconds)	(52.67)	(33.70)	(39.07)	(28.58)	(25.70)	(32.28)	(20.40)	(17.02)	(20.74)	(13.71)
	Commissions	0.02	0.03	0.12	0.08	0.08	0.03	0.05	0.05	0.08	0.03
		(0.16)	(0.26)	(0.50)	(0.28)	(0.27)	(0.16)	(0.21)	(0.22)	(0.50)	(0.17)
	Omissions	2.83	3.37	4.14	3.35	2.63	2.83	2.35	2.02	1.64	1.83
		(2.32)	(2.95)	(3.82)	(2.71)	(2.07)	(2.71)	(2.11)	(2.22)	(1.57)	(1.96)
Two Targets	Time	54.4	47.7	39.2	31.7	25.8	22.5	12.4	6.3	15.1	12.4
minus Single	(seconds)	(35.0)	(28.3)	(27.7)	(23.0)	(19.8)	(32.9)	(23.2)	(19.7)	(17.7)	(10.6)
Target	Omissions	0.93	2.03	2.43	2.67	1.24	2.13	1.81	0.65	0.81	1.11
		(3.12)	(2.63)	(3.43)	(2.24)	(3.24)	(3.57)	(2.28)	(2.52)	(1.90)	(2.37)

Scheffe test indicated that the difference score is more significant in the younger age groups (i.e., 8–12) than in the older age groups (i.e., 13–17). As can be seen in Table 5, this reflects the fact that the changes in the complex task, as compared to the simple task, are steeper over the age groups. The other interactions did not reach significance.

Number of Errors. Separate analyses were conducted for number of *omissions* and number of *additions*. In the analysis of number of additions, none of the effects reached significance. However, number of omissions was significantly reduced with age, $F(9, 782) = 6.12$, $p < .001$, $\eta^2 = .07$, and was lower in the one-digit task compared to the two-digit task, $F(1, 782) = 226.88$, $p < .001$, $\eta^2 = .23$. The Age × Complexity interaction, $F(9, 782) = 3.92$, $p < .001$, $\eta^2 = .04$, is due to the fact that the reduction in number of omissions is steeper in the two-digit task than in the single-digit task. Gender effect and all the other interactions were not significant.

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Digit-symbol test. In the analysis of the number of correctly copied symbols within 120 seconds, all main effects and interactions reached significance. The number of symbols correctly copied increased significantly as a function of age, $F(9, 783) = 155.69$, $p < .001$, $\eta^2 = .64$. Overall, boys (55.16 ± 7.1) completed less symbols than girls (58.87 ± 16.9), $F(1, 783) = 25.95$, $p < .001$, $\eta^2 = .03$. However, this finding should be interpreted cautiously because of the significant Gender × Age interaction, $F(9, 783) = 2.34$, $p < .02$, $\eta^2 = .03$. In most age groups, girls were faster than boys, except at ages 9, 13, and 17 years. The mean and *SD* of the number of correctly copied symbols for boys and girls on this task are presented in Table 3.

Digit span test. In the analyses of the number of digits forward and backward recalled, Age and Complexity were the only effects to reach significance. Overall, the number of digits correctly recalled increased with age, $F(9, 788) = 33.12$, $p < .001$, $\eta^2 = .27$. Ages 8–10 are significantly different from all other age groups; ages 11–13 are significantly different from age 17; and after age 14, the groups did not significantly differ from each other. More digits were recalled in the forward than in the backward task, (7.31 and 5.80, respectively), $F(1, 788) = 405.36$, $p < .001$, $\eta^2 = .34$. The number of digits recalled forward and backward are presented in Tables 4a (boys) and 4b (girls). The task Complexity × Age interaction shows a trend, $p = .038$, indicating that improvement with age of the digits forward task is moderately steeper than that of the digits backward. Boys showed a trend for recalling overall more digits than girls $F(1, 788) = 4.59$, $p < .05$, $\eta^2 = .01$.

Based on the above analyses of all the tests used, Table 5 presents a matrix summarizing the tests that were sensitive to one- and two-years changes. This is an attempt to reflect

Table 3 Means and (*SD*) of the Digit-Symbol Scores for Each Age Group, by Gender.

	Age group (years)									
	8	9	10	11	12	13	14	15	16	17
Boys	(*n* = 39)	(*n* = 37)	(*n* = 41)	(*n* = 38)	(*n* = 42)	(*n* = 41)	(*n* = 37)	(*n* = 59)	(*n* = 46)	(*n* = 35)
	31.82	38.97	42.15	50.21	54.40	55.78	61.76	66.08	74.77	75.80
	(4.93)	(10.06)	(9.55)	(8.48)	(10.66)	(9.28)	(11.10)	(11.86)	(11.42)	(11.44)
Girls	(*n* = 41)	(*n* = 38)	(*n* = 42)	(*n* = 37)	(*n* = 38)	(*n* = 40)	(*n* = 43)	(*n* = 41)	(*n* = 38)	(*n* = 35)
	35.88	40.05	46.50	56.84	58.89	59.10	70.23	72.95	71.37	76.89
	(8.32)	(8.21)	(8.52)	(9.06)	(8.19)	(11.83)	(11.04)	(10.26)	(13.51)	(11.52)

Table 4 Means and (*SD*) of the Digit Span Scores for Each Age Group, by Gender.

	Age group (years)									
	8	9	10	11	12	13	14	15	16	17
Boys	(*n* = 39)	(*n* = 37)	(*n* = 41)	(*n* = 38)	(*n* = 42)	(*n* = 41)	(*n* = 37)	(*n*=59)	(*n*=46)	(*n*=35)
Forward	5.21	5.81	6.49	7.87	7.12	8.34	8.05	7.97	8.51	9.17
	(1.36)	(1.63)	(1.99)	(2.38)	(2.22)	(2.41)	(1.99)	(2.02)	(2.49)	(2.12)
Backward	3.87	4.65	4.78	6.32	5.79	6.07	6.27	6.95	6.81	7.37
	(1.11)	(2.03)	(1.53)	(2.38)	(2.10)	(2.15)	(2.58)	(2.13)	(2.46)	(2.21)
Forward minus Backward	1.33	1.16	1.70	1.55	1.33	2.27	1.78	1.02	1.70	1.80
	(1.61)	(1.99)	(2.10)	(1.95)	(1.96)	(2.57)	(2.26)	(2.14)	(2.33)	(2.27)
Total	9.00	10.31	11.15	14.08	12.58	14.14	14.00	14.77	15.51	16.63
	(1.39)	(2.99)	(2.79)	(4.45)	(3.91)	(4.04)	(4.32)	(3.77)	(4.28)	(3.99)
Girls	(*n* = 41)	(*n* = 38)	(*n* = 42)	(*n* = 37)	(*n* = 38)	(*n* = 40)	(*n* = 43)	(*n* = 41)	(*n* = 38)	(*n* = 35)
Forward	5.20	5.87	5.57	6.89	7.55	7.70	8.02	8.29	8.18	8.24
	(1.40)	(1.74)	(1.21)	(1.99)	(1.89)	(1.91)	(2.21)	(2.29)	(2.35)	(2.09)
Backward	4.15	4.50	4.64	5.92	6.21	5.48	6.51	6.44	6.11	6.79
	(1.22)	(1.71)	(1.28)	(1.98)	(2.41)	(1.60)	(1.76)	(2.24)	(1.99)	(2.04)
Forward minus Backward	1.05	1.37	0.93	0.97	1.34	2.23	1.51	1.85	2.08	1.44
	(1.76)	(1.48)	(1.49)	(2.50)	(2.42)	(1.98)	(2.22)	(2.66)	(2.00)	(2.49)
Total	9.35	10.05	10.34	12.31	13.76	12.86	14.25	14.63	11.14	14.82
	(1.94)	(2.89)	(1.85)	(3.03)	(3.59)	(2.91)	(3.57)	(3.79)	(4.00)	(3.61)

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the sensitivity of the different tests to age on the one hand and on the other hand to detect the age groups in which the changes are most detectable.

As can be seen at the top of Table 5, in general the tests are not sufficiently sensitive to one-year changes. However, all tests were sensitive to the change from years 10 to 11. At the bottom of the table, when the sensitivity of the tests to two-years change is presented, more significant changes were detected. It is clear that changes in the younger children (8 to 12) are more evident than changes in the older children. Actually, all the tests were sensitive to the developmental changes in the younger children. It is important to note that the Cancellation of two digits and the Digit-Symbol tests were sensitive to the developmental changes (two years apart) from age 8 to 15 and from 8 to 17, respectively. The Cancellation of two digits test was almost as sensitive with the exception of the 15–17 year old group, which reached significance only at $p < .03$ level.

In addition to group comparisons, we conducted Pearson product-moment correlation analyses among all the measures used in the previous analyses, which are displayed in Table 6. As can be seen in this table, all measures correlated with each other and with age. Notice that the correlation's magnitude is consistent with findings reported in the previous table. That is, the two tests most sensitive to age change are the Cancellation test and the Digit-Symbol test.

To address the question of which attention tests significantly accounted for developmental variance when order of entry was not specified, we ran a stepwise multiple regression analysis with all seven test measures serving as predictors. As can be seen in Table 7, the Digit-Symbol test entered first, accounting for 60.9% of the variance, followed by the Cancellation of two digits test, explaining an additional 6.6%, followed by the Cancellation of a single digit, accounting for an additional 0.8% of the variance, and finally Trail Making Part

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Table 5 Test Sensitivity to Age Change: Significance of Scores to One- and Two-Year Differentials.

	Attention Tests										
	TMT Digits	TMT Dual	TMT Diff.	Cancel single-target	Cancel 2 targets	Cancel Diff.	Digit Span Forward	Digit Span Backward	Digit Span Diff.	Digit-Symbol	Age Difference
Comparison of consecutive ages											
8–9	***	***		***	***		*			***	6
9–10		***	***	**	*					***	5
10–11	***	***	**	***	***		***	***		***	8
11–12				***	***						2
12–13									**		1
13–14										***	1
14–15					***	***					2
15–16				***		**				**	3
16–17											
Total	2	3	2	5	5	2	2	1	1	5	
Comparison every two years											
8–10	***	***	***	***	***	***	***	***		***	9
9–11	***	***	***	***	***	**	***	***		***	9
10–12	***	***	***	***	***	**	***	***		***	9
11–13	*	***	**	***	***	**			**		7
12–14				*	***	**				***	4
13–15				*	***	**		**	**	***	6
14–16				***	***					***	3
15–17				***		**				***	3
Total	4	4	4	8	7	7	3	4	2	7	

* $p < .01$; ** $p < .005$; *** $p < .001$.

Table 6 Correlations Between Attention Tests.

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	Age
(1)	TMT digits	–	.69	.67	.68	–.40	–.39	–.66	–.60
(2)	TMT dual		–	.67	.70	–.47	–.49	–.69	–.66
(3)	Cancellation single target			–	.84	–.48	–.44	–.77	–.75
(4)	Cancellation 2 targets				–	–.46	–.43	–.78	–.77
(5)	Digit Span Forward					–	–.55	.48	.47
(6)	Digit Span Backward						–	.48	.41
(7)	Digit-Symbol							–	–.79
	M	37.00	91.29	99.20	127.30	7.31	5.80	57.42	
	SD	17.71	48.80	33.23	52.65	2.31	2.20	17.02	

Note: All correlations significant at $p < .001$.

Table 7 Results of Stepwise Multiple Regression for Attention Tests Predicting Age.

Step	Test	Multiple R^2	R^2	R^2 Change
1	Digit-symbol		.609*	.609*
2	Cancellation of two digits		.675*	.066*
3	Cancellation of one digit		.682*	.008*
4	Trail making part B		.688*	.006*

*$p < .001$.

B accounted for an additional 0.6% of the variance. Thus, these four tests produced a multiple correlation of $R = .831$, accounting for 69.0% of the developmental variance.

DISCUSSION

Assessment of attention is a key issue in the study of neuropsychological development. There exist both acquired (e.g., head injury) and organic (e.g., attention deficit/hyperactivity disorder [ADHD]) deficits in attention. Because attention is quite developmentally dependent, normative tests are required in order to determine whether the performance on the attention tasks is within the range of normal performance or deficient for a given age and gender.

In this study we attempted to achieve three objectives: to collect developmental Hebrew norms for four frequently used attention tests, to analyze the developmental sensitivity of each test, and to trace developmental changes in attention across ages and to detect when the changes are more or less pronounced across the age range tested (i.e., 8–17). The results of the present study clearly indicate that although all tests showed age effects, some of the tests were more sensitive than others. The statistical analyses we employed — comparison of means, correlations, and multiple regression (see Tables 5–7) — consistently indicate that the three most age-sensitive tests are Digit-Symbol and the Cancellation tests (one and two digits). In Cohen's (1993) conceptual framework, these tests, but not the other two (TMT and Digit Span), assess sustained attention. That attentional component is based on adequate functioning of the three other components. Furthermore, the Digit-Symbol task in particular is considered to require multiple resources (memory, visual tracking, perceptuo-motor skills, and time constraining). Thus,

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age-related changes in the performance on the Digit-Symbol test may be seen as reflecting the maturation required to integrate these abilities efficiently.

It should be noted that the Digit-Symbol and Cancellation tests, with their systematic scanning demands, resemble classroom learning activities (i.e., reading, writing, copying from a blackboard) more than the other tests. Thus, classroom experience may be more expressed in performance of those particular attention tests than in the others. Unlike TMT, the Cancellation test requires serial scanning on horizontal lines, similar to reading and writing. The older the child, the more school experience he or she has on similar tasks. This differential experience might reinforce maturation differences. In contrast, children of any grade level are relatively unfamiliar with the other tasks (i.e., TMT and Digit Span). Accordingly, it may be expected that the Digit-Symbol and Cancellation tests would be the most sensitive in detecting children with learning disabilities, on the assumption that they benefit less than normal children from transfer to those tests from school learning experience. We believe, however, that performance patterns on those tests reflect first and foremost a late maturation of sustained attention, rather than an effect of classroom experience. Support for this interpretation comes from the continuous performance test (CPT), in which visual scanning is not involved. Conners, Epstein, Angold, and Klaric (2003) found that performance on the CPT continuously improved in children between 9 and 17 years of age. Similar to our findings, the improvement was steeper in the earlier years.

The other interesting finding of our study is that the younger age groups (8–11) are more dissociable than the older age groups (12–17). This indicates that changes in attention are more pronounced in the early years and stabilize in the later years. This pattern was true for all tests used (see Table 5). These findings are consistent with previous reports using attention tests reflecting sustained attention, with rapid changes up to 10 years of age, and only minor improvements thereafter to 12 years of age (maximal age studied) (e.g., Betts et al., 2006). A similar pattern was also found for focused and sustained attention tasks, which improved up to 10 years of age (Klenberg et al., 2001).

One of the advantages of the present study is that we tested children up to the age of 17, whereas other studies tested attentional development in children only up to the age of 12 (Betts et al., 2006; Klenberg et al., 2001; Lockwood et al., 2001; Mirsky et al., 1991; Rebok et al., 1997). This range, and our large sample size providing more statistical power, enabled us to detect changes at older ages not previously reported. Our findings are consistent with the findings of other studies (Conklin, Luciano, Hooper, & Yarger, 2007; Manly et al., 2001) that tested a similar age range and used different tests for selective attention, sustained attention, and attentional control. Specifically, in the present study, the latest change was showed through age 17 (for Cancellation two digits, Digit-Symbol, and TMT Part B) through age 16 (for Cancellation one digit), through age 14 (for TMT Part A and Digit Span backward), and through age 13 (for Digit Span forward). In terms of the attentional components posited by Cohen (1993), Sustained Attention (Digit Cancellation and Digit-Symbol) reach maximal performance later than Attentional Capacity and Response Selection (Digit Span and TMT). Thus, while all tests are sensitive to development over the younger age groups, the Digit-Symbol and Cancellation tests are preferentially sensitive to changes over the older age groups (12–17). The fact that these attentional tests are not very sensitive to maturation in adolescence does not reflect a limitation of the tests or ceiling effects. In our opinion, it reflects the development of the attentional system, which develops quickly up to about the age of 11 and then continues to develop at a much slower rate.

As indicated by the significant task Complexity × Age interactions for the TMT and Cancellation tests, changes over the age groups are steeper for the complex tasks than for

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the simple tasks. Furthermore, maximal performance is reached at a later age for the complex tasks than for the simple tasks. These findings support the notion that attention is composed of subprocesses (Cohen, 1993; Mirsky et al., 1991; Posner & Petersen, 1990). Even when embedded within the same task as two qualitatively different complexity levels, they may be differentially affected by development. The findings that the more complex tasks are more sensitive to the later developmental age than the simpler tasks are consistent with the notion that the more complex components, are presumed to require more working memory and strategic planning, thus being more strongly associated with frontal lobe function. This pattern of results may be understood in light of the notion that functions supported by the frontal lobes are the most sensitive to development (Conklin et al., 2007).

The interpretation of the differential maturation rate of performance on the various tests as reflecting differential maturation rate of multiple attentional components should be done cautiously. As described in the introduction, the mapping of the tests onto diverse attentional components varies from one model to another. The two last-to-mature tests, Cancellation and Digit-Symbol, are representative according to Mirsky's et al. (1991) model of the focus-execute factor. But TMT also reflects the same factor and did not show the same sensitivity for adolescent ages as the first two tests.

The gender effect in the different attention tests presents a complex pattern. Consistent with previous reports in the literature (Baron, 2004; Klenberg et al., 2001), girls are faster than boys on the Digit Cancellation and Digit-Symbol tests. Similarly, boys tended to perform better than girls in the Digit Span test, this in accordance to Jorm et al. (2004) testing adults that reported that males outperformed females in the digits backward test. No gender effect was found in the TMT. A possible explanation for these findings is that on tasks that are based primarily on processing speed (i.e., Digit Cancellation and Digit-Symbol), girls outperform the boys. On the other hand, when task demands are based primarily on working memory (i.e., Digit Span), boys show an advantage over girls. The lack of gender effect in the TMT is possibly due to the fact that this task involves both speed of processing as well as memory span demands.

One limitation of the present study is that its constituent tests were administered by a number of different examiners. This was necessary in order to collect the data simultaneously from a range of geographically distant schools. However, all the examiners were trained and supervised by the same instructor. Another limitation is the fact that we used the subtests (i.e., Digit-Symbol Test and the Digit Span) from the WISC-R version, which, as explained above, is the version in clinical use in Israel. Caution should be exercised in comparing the scores reported here with those of later test versions.

Although the primary goals of this study were clinical, as emphasized above, these findings contribute to our understanding of attentional processes and their measurement, as well as the effects of development on various components of attention.

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