

# Children's search strategies and accompanying verbal and motor strategic behavior: Developmental trends and relations with task performance among children age 5 to 17

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## Abstract

Children's reported use of single and multiple search strategies during a matching numbers task, along with accompanying verbal (private speech, self-talk) and motoric (finger pointing, place-holding) strategic behaviors were examined with a large, nationally representative cross-sectional sample ( $n = 1979$ ) of children between the ages of 5 and 17. Strategic searching increased with age, especially between the ages of 5 (15% strategic) and 9 (63%), with 9-year-olds' strategy use being similar in many ways to that of 17-year-olds. Use of multiple search strategies similarly increased with age. Relations between reported strategy use and task performance were positive for 5- to 7-year-olds, nonexistent for 8- to 12-year-olds, and slightly negative for adolescents. Self-talk, although relatively rare during this task, was a performance asset for young children who were strategic and a liability for young children who were non-strategic. Pointing was negatively related with performance for those who were strategic and irrelevant for those non-strategic.

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A key topic within contemporary cognitive development research is children's strategic behavior during memory and problem-solving tasks. Researchers have moved away from early, simple notions that (a) children at a given age use a single, global strategy or algorithm for solving a variety of problems, (b) strategies are easily placed on a developmental ladder of maturity, and (c) as they develop children replace their less-mature approach to solving a problem with a new and more effective strategy. Instead, children's strategic behavior during problem-solving tasks is now seen as much more variable and complex, with youngsters using multiple strategies both

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across tasks and within multiple trials of a single task, and both strategy use and strategy effectiveness depending on a host of individual, contextual, and task factors (Bjorklund & Douglas, 1997; Kuhn, Garcia-Mila, Zohar, & Anderson, 1995; Miller, 1994; Siegler, 1996). The present study utilized a large ( $n=1979$ ), nationally representative, cross-sectional sample of children between the ages of 5 and 17 to examine age-related changes in: (a) children's reported use of single and multiple search strategies during a searching and matching task, (b) children use of self-verbalization and finger pointing/place-holding as supplementary strategic behaviors during the task, and (c) relations between children's strategic behavior, age, task performance, and standardized achievement.

Strategy development researchers have called for more work to be conducted on children's spontaneous (as opposed to trained) strategy use (Bjorklund, Miller, Coyle, & Slawinski, 1997) and for strategy research to be conducted using a wider variety of tasks and settings than the standard memory recall and math tasks commonly employed (Bjorklund & Rosenblum, 2001; Crowley & Siegler, 1993; Ellis, 1997). The present study helps in this effort by exploring spontaneously occurring strategies used by children and adolescents during a number searching/matching task novel to the literature (and to the participants). Limited information exists at present on the types of strategies and the effectiveness of strategies that children use during search tasks.

Search behavior is typically considered strategic if it is systematic (i.e., follows some kind of pattern, structure, or plan, rather than being either random or driven by spatial proximity alone) and/or if it is selective (only relevant targets/locations/items are searched) (Davidson, 1991; Klayman, 1983). Using such criteria, researchers have found a general pattern of children's searches becoming increasingly strategic (systematic and selective) with age, with children age seven and younger tending not to be particularly strategic, and with search behavior starting to resemble adult-like systematicity at about 12 years of age (Davidson, 1991; Klayman, 1983; Miller, 1990; Vanden Avond, 1997). Vanden Avond (1997) found with second-, fifth-, and eighth-graders, that although the particular way in which youngsters' searches were systematic (when scanning items across rows and columns on a page) varied across trials, whether or not children's search behavior was strategic, *in general*, was quite consistent across trials. That is, children of all ages, during a task, tended to be either strategic searchers or not. The novel task studied here required children to examine six numbers in a row and determine which two numbers were identical. The number of digits per number in the rows gradually increased from one to seven. The search strategies investigated here include various types of systematic looking for the matching numbers (e.g., looking at the last digit of the numbers first and then the first, searching for the first and second digits of the numbers together as a group, going in order of matching the first, then second, then third digits, etc. . . .).

The present study examines children's retrospective self-reported use of search strategies. Although it is recommended that researchers have measures of observed strategy use or on-line performance data (such as latencies or errors, from which strategy use can be inferred) to go along with children's reports, the literature also shows that retrospective verbal self-reports under certain conditions can be veridical (Crutcher, 1994; Robinson, 2001; Russo, Johnson, & Stephens, 1989). Children's retrospective self-reports of strategy use have now been studied in a variety of different types of tasks, including subtraction (Robinson, 2001), planning (Naglieri & Gottling, 1997; Naglieri & Johnson, 2000; Winsler & Naglieri, 2003), and spatial memory (Bray, Huffman, & Fletcher, 1999), and have been found to be reliable and valid measures of children's actual strategy use. Verbal reports are particularly well-suited to provide information on children's multiple strategy use and on inter- and intra-individual differences in strategy use (Robinson, 2001). Although children's verbal reports have been clearly shown to be accurate (that is, if children say they used

a strategy, they did) such reports, just like other measures, can still be incomplete (that is, not all strategies used may be reported) (Robinson, 2001; Winsler & Naglieri, 2003). The methodology used here for obtaining the self-reports satisfies, for the most part, Ericsson and Simon's (1993) conditions under which children's strategy use self-reports are likely to be veridical. Namely, the child report followed immediately after the task activity, a brief interview process was used, and the relevant task materials were still accessible to the child during the interview.

In addition to exploring the specific search strategies employed/reported by children of various ages, the present study also examined age-related differences in the use and effectiveness of other, more general meta-cognitive, strategic, task-relevant behaviors in which children engaged during the task, namely private speech (self-talk) and finger pointing/place-holding. Private speech has long been studied within the Vygotskian tradition (Bivens & Berk, 1990; Diaz & Berk, 1992; Vygotsky, 1978; Winsler, Carlton, & Barry, 2000; Winsler, Diaz, Atencio, McCarthy, & Adams Chabay, 2000; Winsler, Diaz, & Montero, 1997). However, it is only recently that private speech has been viewed as a strategy in and of itself used during children's problem-solving activities (Winsler & Naglieri, 2003). Overt, task-relevant private speech use by children is seen from Vygotsky's perspective as a domain-general self-regulatory tool that youngsters use to monitor, guide, and organize their thinking and behavior during challenging problem-solving activities (Berk, 1992).

Although much is known about the inverted U-shaped developmental progression of private speech in the early childhood years, such speech has not been the topic of much study during the middle childhood period and beyond (see Duncan, 2000; John-Steiner, 1992; Kronk, 1994; McCafferty, 1994 for rare exceptions). Winsler and Naglieri (2003) showed that overt self-talk, although diminished in both frequency of use and effectiveness throughout childhood, continued to be a strategy used by 20–30% of adolescents engaged in a planning task. In that study, talking out loud to the self was only an effective strategy (i.e., positively associated with performance) among 5- to 7-year-old children even though it was fairly common task-related behavior for all ages studied. Such findings of protracted strategy use without performance gains suggest that utilization deficiencies (the spontaneous production of a strategy without any apparent performance gain) typically seen among younger children (Bjorklund et al., 1997; Miller, 1994) can also occur late in strategy development. Other investigators (Baker-Ward, Ornstein, & Holden, 1984; Fabricius & Cavalier, 1989) have reported that verbal labeling in the context of a memory task is not helpful for children until they are about 6 years of age, even though 4- and 5-year-olds spontaneously use such verbal strategies. One of the goals of the present study was, thus, to determine whether similar age-related trends of continued verbal strategy use without apparent performance gains would be seen for 5- to 17-year-old children engaging in a visual search and matching task.

Another goal of the present study was to explore whether the combination of spontaneous self-verbalization and the use of a particular search strategy is differentially related to task performance relative to the use of a search strategy alone, and to see whether the effectiveness of such strategic combinations varies as a function of age. The effectiveness of a combination of verbal and nonverbal strategies has not been a topic of much research within the strategy development literature (Baker-Ward et al., 1984), however, investigators interested in the verbal regulation of behavior have asked similar questions with preschool children (Mischel, 1996; Vaughn, Kopp, Krakow, Johnson, & Schwartz, 1986). Manfra, Winsler, Chandler, and Ducenne (2002), for example, examined the effectiveness of single (motor or verbal) versus multiple (motor and verbal) strategy use in preschool children's performance on a resistance-to-temptation task. Children who used a combination of both motor and verbal strategies were most successful at the task over children who used only a motor strategy (second most successful), only a verbal strategy (third

most successful), or no strategy (unsuccessful). The present study will examine children's search strategies both with and without the presence of task-relevant verbal and motor behaviors.

Finally, children's use of their fingers in the form of pointing to the numbers or place-holding is also explored in this investigation. Spontaneous gestures and their relationship with speech during communicative explanations and individual problem solving are important for children's learning generally, and for their conceptual and strategic transitions (Alibali, Bassok, Solomon, Syc, & Goldin-Meadow, 1999). Explored here is the frequency of such use of pointing and whether or not it is associated with children's task performance, either alone or in combination with children's speech and search strategies.

The following research questions were addressed in this study: (1) How common is the reported use of each of the search strategies at each age? (2) To what extent are the different strategies associated with improved task performance? (3) Does strategy effectiveness vary by age? (4) Are there age-related differences in multiple strategy use? (5) Is strategy effectiveness different for children with varying levels of competence? (6) To what extent are overt strategic behaviors, such as private speech and finger pointing, associated with performance, and how does this differ by age of child? (7) Does it matter for performance whether reported strategies are accompanied by either overt self-speech and/or finger pointing?

## 1. Method

### 1.1. Participants

Participants included 2156 children (51% female) varying in age from 5 to 17 ( $M=9.3$  years,  $S.D.=3.7$ ), who made up the nationally representative (USA) standardization sample for the development and validation of the Cognitive Assessment System (CAS; Naglieri & Das, 1997), an individually administered test of children's cognitive abilities. Children from 68 sites across the country were recruited via letters/consent forms sent to parents from their children's schools. The sample's composition, by design, closely reflected the U.S. population (1990 census data) on the basis of age, gender, race, Hispanic status, geographic region, parental education, and community setting. The sample was 77% Caucasian, 13% African-American, 3% Asian-American, 1% Native American, 6% "other," and of all these groups, 11% considered themselves "Hispanic." Geographically, 25% of the participants were from the Midwest, 18% were from the Northeast, 33% were from the South, and 24% were from the West. Twenty-six percent were from rural areas. Parental education was as follows: 20% did not complete high school, 29% had a high school diploma, 28% went to some college, and 23% graduated from college. Children with diagnosed needs receiving special education services were excluded from the analyses, yielding a final overall sample of 1979 normally developing children. Data collection took place between Fall 1993 and Spring 1996. The persons who coded the data were the original test examiners who administered the CAS at the many sites. These individuals were typically well-trained graduate students in psychology and education. All examiners were naïve to the research questions of the current study.

### 1.2. Procedure and measures

Participants were individually administered the CAS in a small testing room by qualified, trained examiners during the standardization of the CAS (Naglieri & Das, 1997). Data examined for this study come from one of the CAS planning subtests, namely matching numbers, designed to measure children's impulse control, intentionality, and strategy generation, monitoring, evalu-

ation, and execution in a problem solving context. In the matching numbers task, children search for two identical numbers within a single row of six numbers and then underline the two numbers that are the same. An example item is as follows:

3                      4                      2                      3                      7                      1

In this example, the two 3s would be underlined or circled in order for the item to be counted as correct. For the 5- to 7-year-olds, there are 16 rows of numbers across two pages, and each number is comprised of one to three digits. For the 8- to 17-year-olds, there are 24 rows of numbers on three pages, and each number is comprised of two to seven digits. The digits for this group also increase gradually with subsequent items. For example:

13	38	46	52	38	87
102	321	102	534	734	447
221	223	212	232	223	122

The number of digits per number is constant within each row and increases down the rows from the minimum (top of page) to maximum (bottom of the page). Thus, the last and most difficult row consists of 6, 7-digit numbers. Page two for the 5- to 7-year-olds is comprised of the exact same items/numbers as page one for the older children. After doing two practice items together with explanation from the experimenter, the child was asked to “Find the two numbers that are the same in each row and underline them. If you make a mistake, cross it out and underline your new answer. Work as quickly as you can and tell me when you’re finished.” (Naglieri & Das, 1997, p. 16). The time limit for each page was 150 s, except for the last page, completed only by the 8- to 17-year-olds, for which 180 s were given. The final items and time limits for the task were carefully designed after extensive pilot testing to insure minimal floor and ceiling effects. Specially trained personnel scored and checked all test protocols for accuracy and completeness. Average internal consistency reliability coefficients across ages 5–17 years for performance on the matching numbers task is .75 (Naglieri & Das, 1997).

### 1.2.1. Strategy use and reporting

Standard CAS administration protocol for the matching numbers subtest involves the examiner observing and recording several common behaviors used by children while they are engaged in the task. Thus, on the CAS record form there is a place for examiners to mark off whether or not, during work on any of the matching numbers items, the child “verbalized the numbers” or “put their finger(s) on the numbers.” These two dichotomous (yes/no) indicators by the examiner, thus, served as variables representing whether or not speech or finger pointing/place-holding was observed at least once during the task.

Standard CAS examination protocol also obtains the child’s self-report of their search strategy during the matching numbers subtest. After the child completed all of the pages, and while the test booklet with the pages was still in front of the child, the experimenter inquired about the child’s strategy use by saying the following: “Tell me how you did these” (while the examiner pointed to several items/pages in front of the child, referring to the entire task and not just one row). If the child did not respond, the examiner modified the question to: “How did you find the numbers that were the same?” (Naglieri & Das, 1997, pp. 16–17). The examiner was allowed to clarify the question further if needed (if there was still no child response) and, although not specifically instructed, was allowed to mention the word “strategy” if needed, but examiners were specifically trained to not give any examples of strategies. Examiners noted, on a regular section of the child’s record form, which strategies the child reported using. Six specific and distinct

strategies that were reported frequently by children during pilot testing were listed on the record form. The six systematic search strategies were: (1) *First Digit* (systematically looking primarily at the first digit of all of the numbers in the row), (2) *First Two Digits* (systematically matching the first two digits together as a group in all of the numbers in the row), (3) *First, Last* (systematically matching the first and then the last digit in all of the numbers in the row), (4) *First, Second, Third . . .* (systematically matching the first, then second, then third . . . numbers in the series until done), (5) *First, Last, Middle* (systematically looking at the first, then last, then an interior/middle digit of all of the numbers in the row), and (6) *Last, First* (systematically matching the last and then the first digits in all of the numbers in the row). If the child did not report any particular strategy or if they only said something vague like “I just looked at all the numbers” the child was coded as NOT reporting a search strategy. After the child reporting a strategy, the experimenter asked if they did anything else or if that was it. These dichotomous indicators (Y/N—across the whole task) served as the raw variables used for children’s search strategy reported.

An analysis of the a priori theoretical efficacy of each strategy use per item was conducted. The most effective strategies (in the sense that one could get to a definitively correct answer without guessing if the strategy were used alone and correctly) across all items and age ranges were strategies 4 (first, second, third . . .) and 5 (first, last middle). These strategies lead to correct solutions 100% of the time (as long as “middle” involves grouping multiple digits in the middle for the longer digit items). Strategy 6 (last, first) was next, leading to the correct answer on 94% of the items for the 5- to 7-year-olds, and 33% for the 8- to 17-year-old items. Use of strategy 3 (first, last) only gets the right answer 88 or 29% of the time, respectively, depending on the version of the item booklet used. Strategy 2 (first two digits) yields the correct answer 75% of the time for the easier, and 17% of the time for the more difficult items. Finally, strategy 1 (first digit only) gets to the right answer by itself 31% of the time for the younger children and 0% for the older children. It is important to note, however, that although the above strategies alone might get the child to the right answer, they also take time and children may have chosen to do other seemingly faster (and unreported) strategies. Also worth noting is that most all of the strategies work better for the items with smaller numbers of digits.

In addition to the six systematic search strategies discussed above, data were also collected on children’s reports of two other behaviors during the task that we did not count as being systematic search strategies. First was the child reporting that s/he simply scanned or looked at all of the numbers once or multiple times (in no particular order) until they saw the match. This behavior we called “scanned entire row.” Second, if children reported any other task-related behavior or strategy during the task that did not fall in any of the above, they were scored as reporting an “other” strategy/behavior. Unfortunately, this “other” category included basically any task-related behavior reported by the child, including both other real (but rare) search strategies (i.e., looking for the first odd number in the series) and any other idiosyncratic responses made by the child about the way s/he did the task (i.e., I picked the middle two numbers always regardless of whether it was correct, I just guessed, I just saw it, etc. . . .). Because we did not have the qualitative data for what children said here and thus could not determine whether what was reported was really a search “strategy,” these “other” data should not be taken to clearly indicate the use of another systematic search strategy. They are reported in this investigation simply for completeness.

### 1.2.2. Task performance

Task performance for matching numbers is calculated by first taking a rate score for each of the two to three pages (which is [number of items correct plus 10] squared, divided by the number of seconds it took the child to complete the page), and then summing these ratio scores to make

an overall scale score (Naglieri & Das, 1997). As is standard practice for such standardizations, this task performance score (which was the only task performance data available) rewards both accuracy/correctness and speed and puts both into one metric. The addition of the number 10 and squaring were performed in order to ensure a number greater than 1. This sum of the rate/ratio scores was then converted to a standard score ( $M = 10$ ,  $S.D. = 3$ ) for each age year and this was used for all analyses. Thus, a 10-year-old who received a standard score of 16 performed two standard deviations higher on the task than the rest of the 10-year-olds in this standardization sample.

### 1.2.3. Standardized achievement

A sub-sample of 1292 children was also administered the Woodcock–Johnson–Revised (Woodcock & Johnson, 1989) standardized achievement test. The overall “skills cluster” standard score, which aggregates across children’s achievement in math, spelling, and reading, was used ( $M = 100$ ,  $S.D. = 15$ ). The observed mean was  $M = 101.3$ ,  $S.D. = 15.8$ .

## 2. Results

Preliminary analyses revealed no gender differences in search strategy use, strategic behavior (speech, pointing), strategy report, nor in relations or interactions between strategy use and performance, and thus gender was ignored for the rest of the analyses. Consistent with previous research (Naglieri & Rojahn, 2001), however, girls did do slightly better (standard score  $M = 10.53$ ,  $S.D. = 2.91$ ) on the matching numbers task than boys ( $M = 9.86$ ,  $S.D. = 2.97$ ),  $F(1,1961) = 26.06$ ,  $p < .001$ . First, age-related trends in children’s reported strategy use are described. Then, associations between strategies and performance are explored. Then children’s report of multiple strategies is discussed along with an analysis of the search strategies with and without verbal and/or motor accompaniment. Finally, relations with achievement are discussed.

### 2.1. Strategy use by age

#### 2.1.1. Reported search strategies

The percentage of children at each of the different ages who reported using each of the six search strategies is plotted in Fig. 1. Fig. 2 provides the overall percentage of children at each age that reported using zero, one, or two or more of the search strategies. The mean number of strategies reported at each age (not counting the “other” category) is provided in Table 1. Older children were more strategic than younger children. Only 14–23% of the children aged 5–6 reported using at least one systematic search strategy, whereas this figure climbed to 65–71% for the adolescents. Older children were more likely to report strategy use than younger children (point-biserial correlation between age in years and at least one strategy reported [Y,N]  $r = .35$ ,  $p < .001$ ). Also the number of search strategies used increased with age  $r = .34$ ,  $p < .001$ . However, the increase in the number of strategies reported by age took place mostly among the younger children, with children 9 and above showing a similar number of strategies reported.

Overall strategy use by age is plotted in Fig. 2. What is clear from these data is that much change takes place between the ages of 5 and 9 and then patterns stabilize somewhat from ages 10 to 17. The percentage of children who reported not using any strategy dropped from 85% at age 5, to 36% by age 9, and then remained relatively stable with about one-third of children of all ages after 10 reporting no clear search strategy used. Similarly, reporting one strategy increased quickly with age for the youngest age group (until age 9) and then leveled off after that for the



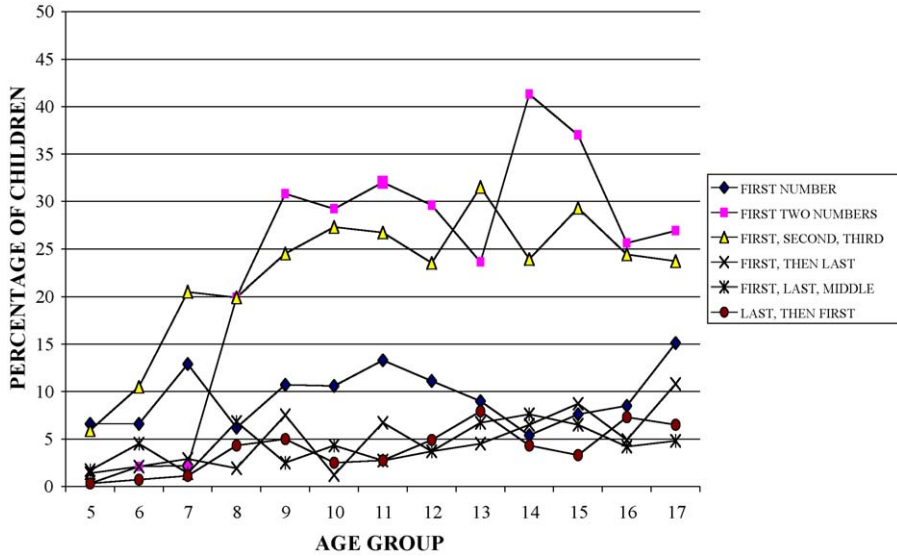


Fig. 1. Age-related trends in the report of six specific search strategies.

older children. Reporting the use of two or more strategies during the task, however, increased more steadily with age in a slightly more linear pattern from the youngest to the oldest age groups.

Linear age trends visible from Fig. 1 were confirmed statistically via logistic regression analyses with age (in years) entered as the independent variable and the relevant dichotomous strategy use variable entered as the dependent measure in turn. Effect size estimates for logistic regression are typically expressed in multiplicative odds ratio terms. The two search strategies that showed the greatest linear increase in use with age were looking for the first two numbers in the series

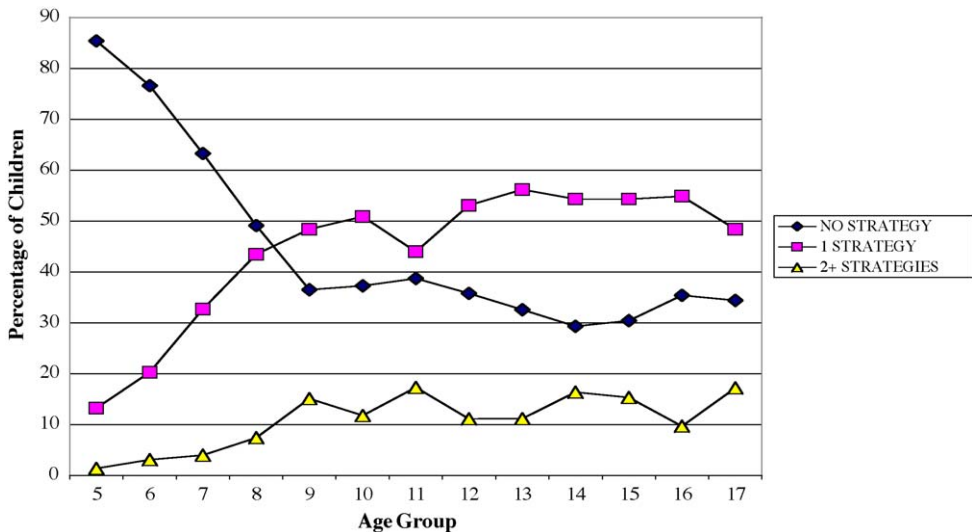


Fig. 2. Age-related trends in children’s overall strategy report (no strategy, 1 strategy, 2+ strategies).



Table 1  
Number of strategies reported and percentage of participants observed to use other strategic and non-strategic behaviors, by age

	5-year-olds <i>n</i> = 294	6-year-olds <i>n</i> = 289	7-year-olds <i>n</i> = 279	8-year-olds <i>n</i> = 165	9-year-olds <i>n</i> = 168	10-year-olds <i>n</i> = 173	11-year-olds <i>n</i> = 80	12-year-olds <i>n</i> = 81	13-year-olds <i>n</i> = 90	14-year-olds <i>n</i> = 93	15-year-olds <i>n</i> = 92	16-year-olds <i>n</i> = 82	17-year-olds <i>n</i> = 93
Number of strategies reported													
<i>M</i>	.16	.27	.41	.59	.81	.75	.84	.76	.83	.89	.92	.75	.87
S.D.	.42	.51	.58	.65	.75	.67	.87	.68	.82	.71	.92	.66	.84
Other strategic behaviors													
Finger placement	12.2	17.1	15.8	20.5	18.9	25.5	25.3	23.5	19.1	16.3	18.5	26.8	22.6
Speech	8.7	2.1	1.4	6.2	5.0	.6	4.0	2.5	5.6	2.2	0.0	4.9	1.1
Other													
Non-systematic scan of entire row	28.9	40.6	40.3	32.9	26.4	24.2	24.0	24.7	24.7	30.4	23.9	24.4	26.9
Other behavior/"strategy" reported	41.8	42.3	37.8	40.4	35.2	39.1	40.0	37.0	39.3	31.5	32.6	40.2	46.2

together at the same time ( $B = .214$ , Wald  $\chi^2(1) = 166.88$ ,  $p < .001$ , odds of use are multiplied by 1.24 with each year of age), and going in consecutive order by matching the first number first, then the second, and then the third, etc. ( $B = .10$ , Wald  $\chi^2(1) = 44.53$ ,  $p < .001$ , odds of use are multiplied by 1.11 with each year of age). The other four searching strategies showed slight but still statistically significant linear increases with age.

### 2.1.2. Overt strategic behavior

Table 1 also provides the percentage of children at each age who were observed to use their finger as a placeholder or who said aloud one or more of the numbers in the series to the self during their searching. Using one's finger to keep place increased with age from age 5 (12%) to 10 (25%), slumped a bit for early adolescence, and then remained at about 25% for the adolescents. Saying one or more of the numbers out loud while searching was relatively rare but most frequent among the 5-year-olds (9%) and reduced to about 1% for the oldest age group, with some slight ups and downs along the way.

### 2.1.3. Other

Also listed in Table 1 is the percentage of children at each age who reported simply scanning the row of numbers to find a match in a non-systematic fashion. About 25% of children across all ages reported doing this (either by itself or in addition to other search strategies reported) with the younger children (ages 6–7) reporting doing this more often than the older children. This is likely due to the fact that with the simpler items, a systematic search strategy is less needed. Finally, the percentage of children who reported engaging in an undetermined “other” strategy or behavior during the task is also reported in Table 1. Here we see that a flat 40% or so of the children across all age groups reported some “other” type of behavior during the search task.

## 2.2. Relations between age, strategies, and task performance

### 2.2.1. Search strategies

To test whether search strategies and overt strategic behavior were related to task performance and to determine whether such relations, if present, were consistent across all ages, a series of moderated multiple regression analyses (one for each strategy) was conducted with task performance on the matching numbers task as the dependent variable and age (continuous in years), any search strategy use (yes, no), and the cross-product (age  $\times$  strategy use) interaction term included as predictors. Overall, use of any of the six search strategies interacted with age of child in predicting performance,  $F(3,1918) = 5.19$ ,  $p < .05$ . The age coefficient was significant,  $b = .10$ ,  $t = 3.01$ ,  $p < .01$ , as was strategy report,  $b = .23$ ,  $t = 3.50$ ,  $p < .001$ , and the age by strategy report interaction,  $b = -.24$ ,  $t = -3.14$ ,  $p < .01$ . To understand and report the nature of this interaction with age, age was categorized into three groups (early childhood ages 5–7, middle childhood ages 8–12, and adolescence ages 13–17). For the 5- to 7-year-olds, report/use of any of the search strategies was associated with a modest performance advantage (Cohen's effect size  $d = .29$ ). No strategic performance advantage was visible for those in middle childhood ( $d = .02$ ). For the adolescents, those who reported/used one or more of the search strategies actually did slightly poorer on the task on average than those who did not ( $d = -.12$ ).

Similar regressions were run for each of the particular strategies reported. There was a significant although small ( $d = .17$ ) positive main effect for reporting the first number strategy,  $F(3,1918) = 3.13$ ,  $p < .05$ . The age coefficient was significant,  $b = .05$ ,  $t = 2.08$ ,  $p < .05$ , as was

strategy report,  $b = .13$ ,  $t = 2.06$ ,  $p < .05$ . Although the age by strategy use interaction was not statistically significant for this particular strategy, the trend observed was for performance differences between strategic and non-strategic children to be present just for the younger two age groups and not the adolescents. The only other individual reported strategy found to be related to performance was the first, second, third . . . until done strategy,  $F(3,1918) = 4.63$ ,  $p < .05$ . Here, age was significant,  $b = .08$ ,  $t = 2.96$ ,  $p < .01$ , as was strategy report,  $b = .22$ ,  $t = 3.16$ ,  $p < .01$  as was the age by strategy report interaction,  $b = -.23$ ,  $t = 3.26$ ,  $p < .001$ . In this case, using/reporting this strategy was effective for the 5- to 7-year-olds ( $d = .35$ ) but not so for the older children ( $d = -.11$ ) nor adolescents ( $d = -.17$ ).

### 2.2.2. Overt strategic behavior

Similar moderated multiple regressions were run for finger pointing and for private speech use. Placing one's finger on one or more numbers as a placeholder while searching interacted with child age to negatively predict task performance, overall  $F(3,1918) = 5.81$ ,  $p < .05$ . Finger placement was irrelevant for performance among the 5- to 7-year-old group ( $d = .08$ ), however, it was an ineffective strategy for the older children ( $d = -.21$ ) and adolescents ( $d = -.32$ ), with pointers at the older ages doing poorer on the task than those that did not, interaction term  $b = -.13$ ,  $t = 1.96$ ,  $p < .05$ . Similarly, saying the number(s) out loud to oneself while searching also related to performance in different ways for different age groups, overall  $F(3,1918) = 5.65$ ,  $p < .05$ . Overall, talking out loud during the task was associated with poor performance on the task among the youngest group ( $d = -.60$ ), and the middle childhood group ( $d = -.22$ ), but was not related to performance among the adolescents ( $d = -.04$ ), interaction term  $b = .13$ ,  $t = 2.22$ ,  $p < .05$ .

Finally, children's reports of non-systematically scanning the entire row for the match and their reports of engaging in some "other" undefined behavior/strategy were not associated with children's task performance in any way according to the same type of analyses conducted above.

## 2.3. Multiple strategy use

### 2.3.1. Search strategies

To examine whether reporting more than one strategy was better than only one search strategy, two types of analyses were conducted. First, a simple correlation between total number of different strategies reported (range = 0–6) and task performance revealed no overall association ( $r = .04$ , n.s.). Because strategy use interacted with age above in predicting performance, a second analysis was conducted, namely, an ANOVA with task performance as the dependent measure and a categorical variable representing multiple strategy use (0 strategies used, 1 strategy used, and 2+ strategies used) and age group (5–7, 8–12, 13–17) as the independent variables. This analysis revealed no significant main effects, but a significant age by number of strategies interaction,  $F(4,1913) = 3.77$ ,  $p < .005$ , showing that although for the middle childhood and adolescent groups there were no performance differences as a function of number of strategies used, for the 5- to 7-year-olds, those who reported using two or more strategies ( $M = 11.5$ , S.D. = 2.91) did better than those who only used one strategy ( $M = 10.6$ , S.D. = 2.95,  $d = .32$ ).

### 2.3.2. Combination of search strategies and overt strategic behaviors

Up until now, we have been reporting overall associations between the use of the search strategies and performance (regardless of the use of speech or pointing), and associations between the overt strategic behaviors and performance (irrespective of whether or not the child's search behavior was strategic). The picture is more interesting when one examines the effect of the

co-occurrence of covert search strategies and overt strategic behaviors. To examine this, a two (any search strategy used—Y/N) by two (pointing—Y/N), by three (age category—early, middle, adolescent) ANOVA was conducted with task performance as the dependent measure. The three-way interaction between search strategy use, pointing, and age group was not significant  $F(2,1910) = .32$ , n.s. However, the two-way interaction between search strategy use and pointing was,  $F(1,1910) = 4.69$ ,  $p < .05$ . This indicated that across all ages, using one's finger as a placeholder is irrelevant for search performance for those who did not search strategically (pointers  $M = 9.96$ , S.D. = 2.85, non-pointers  $M = 10.04$ , S.D. = 3.03), but for those who did use a systematic search strategy, pointing was linked with poorer performance (pointers  $M = 9.52$ , S.D. = 2.65, non-pointers  $M = 10.53$ , S.D. = 2.9). The children who did the best on the task were those who used a search strategy and did not use their hands.

The same type of three-way ANOVA to examine whether private speech use mattered for those children who were or were not strategic could not be conducted due to small individual cell sizes, so patterns were explored separately within each age group. Because only 3.7% ( $n = 71$ ) of the participants total ever talked to themselves during the task, and only 24% ( $n = 211$ ) of the young children were strategic, there was only one child in the youngest age group who both used self-speech and searched strategically. Interestingly, the 5-year-old girl who did this performed extremely well on the matching numbers task (standard score = 15), much higher than the 210 similarly strategic but silent youngsters ( $M = 10.65$ , S.D. = 2.95). For the 5- to 7-year-olds who were not strategic in their searching, talking was linked with somewhat poorer performance ( $M = 8.13$ , S.D. = 3.07) compared to being silent ( $M = 9.91$ , S.D. = 2.90). Thus, for the 5- to 7-year-olds who were being strategic, talking out loud appeared to help, however, saying numbers out loud to oneself without a search strategy appeared to be a liability for the youngest children. For the older two age groups, it did not matter for performance among the strategic children nor among the non-strategic children whether children said the numbers out loud.

#### 2.4. *Relations with achievement*

Analyses were conducted to assess the extent to which task performance, search strategy report, and strategic behavior were associated with children's academic achievement, as measured by the Woodcock–Johnson. Overall, achievement was positively associated with performance on the task ( $r = .41$ ,  $p < .001$ ). Further, high-achieving children were slightly more likely to report using a search strategy (point biserial  $r$  with dichotomous strategy use variable = .15,  $p < .001$ ), and they reported slightly more strategies ( $r = .13$ ,  $p < .001$ ), compared to lower achieving children. Achievement was not related to pointing ( $r = -.05$ , n.s.). A similarly very small negative association between achievement and speech use ( $r = -.06$ ,  $p < .05$ ) did happen to reach statistical significance with this very large sample. Finally, a series of moderated multiple regression analyses was conducted to determine if search strategy use and the strategic behaviors of talking or pointing interacted with ability in predicting task performance. No significant interactions were found, indicating that strategy effectiveness was no different for high versus low-achieving children.

Given that strategy reporting was associated (albeit slightly) with achievement, we felt it important to re-visit the findings discussed above on relations between strategy use and performance, while controlling for children's achievement. The only finding that changed when controlling for achievement was the negative association reported above between talking out loud and performance among the 5- to 7-year-olds. This effect disappeared when Woodcock–Johnson scores were included as a covariate. Thus, the observed negative effect of talking aloud on performance for

the youngest children is explained by the fact that high achieving children are simply somewhat less likely to talk aloud during this task, not by talking per se being directly bad for performance.

### 3. Discussion

Developmental change in children's reported search strategies was observed in the present study. Older children were more likely to search strategically than younger children, with the greatest increases taking place between 5 and 9 years of age. Reporting the use of at least one of the search strategies increased from 14% at age 5 to 63% by age 9, and then leveled off after that, fluctuating between 60 and 70% for each of the older age groups 10 and beyond. In terms of the developmental profile of particular search strategies, chunking together the first and second number as a group for searching showed the greatest increase in slope between the ages of 5 and 9. Also, the strategy of going in order digit by digit, by finding the first, then the second, then third number showed strong linear increases in frequency from the youngest age group up until adolescence. These findings are consistent with previous research (Davidson, 1991; Klayman, 1983; Miller, 1990; Vanden Avond, 1997) showing that 5- to 7-year-olds as a group (although they can be strategic on other tasks, see Woody-Ramsy & Miller, 1988) are not particularly strategic when it comes to searching, and that children become more strategic with age. However, the present study finds the age at which children's strategic search behavior plateaus and resembles adult usage to be earlier (9–10) than previously suggested (age 12). The relatively simple search task used here may not have required particularly sophisticated (or "adult-like") search strategies. The earlier arrival of the developmental plateau found here could be a function of the particular task employed.

It is interesting to note that a full third of children after the age of 9 did not report using one of the search strategies. It may be that these children are in fact searching systematically but that they either could not articulate or chose not to report their strategy. Or the older children in this study who failed to report a strategy may have been using one without awareness. Another possibility is that a substantial minority of older children are able to encode and scan a series of numbers of up to seven digits in one fairly automatic step and do not have to break the task down into smaller specific search strategies. Potentially supporting this hypothesis is that adolescents who did not report using one of the six strategies did perform slightly better on the task than those who did. However, the 25% of children who reported simply scanning the entire row in one sweep in no particular order did not perform differently on the task than those who did not report this behavior, suggesting that there might have been something else strategic that the adolescents were doing.

In contrast to the above pattern for adolescents, search strategy use/reporting for the youngest children, age 5–7, appeared to be helpful. Those who reported using a search strategy did better on the task than those who did not. The fact that use of the strategies discussed here was effective for the youngest children, irrelevant for those in middle childhood, and associated with poor performance among adolescents, suggests that substantial developmental shifts take place in how children negotiate search tasks like this one, in the strategies children report, and in the strategies that work well for them. Strategies, at least in some contexts, do not always get more effective with increased age.

Another vantage point from which to interpret the finding that the reported search strategies were effective for the younger children but not for the older youth is the notion of a utilization deficiency (Miller, 1994)—children spontaneously using a strategy without reaping any apparent task gain. Although utilization deficiencies are typically found during the early stages of strategy development and among younger children when the developmental outcome is that the strategy

eventually becomes useful (Bjorklund & Coyle, 1995; Bjorklund et al., 1997), it appears from this investigation that utilization deficiencies can also appear after the period in which the strategy may have been effective. Persistence of relatively ineffective strategies by children when other strategies are available appears to be common and an important component of strategy selection (Siegler & Stern, 1998). The present study shows considerable use (or reporting) of apparently ineffective strategies throughout adolescence. Again, however, it is important to consider the task. Unlike many tasks used in the strategy literature where a more diverse array of simple to complex strategies is available to choose from, the strategic searching options explored here were more limited.

Strategy effectiveness did not interact with ability to predict performance in this study. That is, whether or not search strategy reporting was associated with performance gains on this particular searching task did not differ for those who were either strong or weak academically. Although a number of investigators have found that strategy use can at times compensate for low ability and/or achievement, such that a strategy is effective for low achievers but either not associated or negatively associated with performance for highly competent children (Bjorklund & Schneider, 1996; Gaultney, Bjorklund, & Goldstein, 1996; Winsler & Naglieri, 2003), this is not always the case. Relations between strategy use and performance are quite complex, with a variety of factors, including age, task, prior knowledge, intelligence, and motivation influencing whether or not the use of a particular strategy will lead to increased performance (Bjorklund & Douglas, 1997).

Although multiple strategy use appears to be the norm for children's cognitive activities (Bjorklund & Rosenblum, 2001; Siegler, 1996), the present study did not find multiple search strategies to be common. Only 10–17% of children in the age groups of 9–17 reported using more than one search strategy. Also, although the effect size was small ( $r = .13$ ), there was an association between the number of strategies reported and children's achievement. The relatively low frequency of multiple strategy reporting observed here is likely due to a combination of the nature of the number matching task itself (there are only so many ways to search systematically for 1- to 7-digit numbers in a row, and many of the children did not appear to need strategies to do well), the limited number of particular search strategies that we explored, and the methodology used. This suggests that the task setting and the number and diversity of relevant strategies available to children are related systematically to their reporting of multiple strategies.

Also explored in the present investigation was children's observed use of verbal (private speech) and motor (pointing/place-holding) task-directed strategic behaviors during the task. Saying the numbers out loud to oneself was relatively rare overall on this task and decreased with age, with only 9% of the 5-year-olds using private speech and this reducing to 1% for the oldest adolescents. Although a reduction with age in the frequency of children's private speech is consistent with previous research (Bivens & Berk, 1990; Winsler et al., 2000a, 2000b; Winsler & Naglieri, 2003), most prior investigations (using different tasks) find considerably larger proportions of children of all ages spontaneously engaging in overt self-talk. Winsler and Naglieri (2003), for example, found 43% of their 5-year-olds and 10% of their 17-year-olds engaging in overt private speech during a planning (connect-the-numbers) task. Other studies with 3- to 6-year-old children typically report 70–100% of children spontaneously talking out loud to the self during problem-solving tasks in the classroom or in the lab (Berk & Spuhl, 1995; Winsler et al., 1997, 2000a, 2000b). Strong task effects for private speech are known to exist (Frauenglass & Diaz, 1985) and that is the best explanation available for the low incidences of self-talk observed here. Verbal mediation is apparently not particularly necessary for this primarily visual searching and matching task.

Although speech was relatively rare, it did interact with children's strategic searching to predict performance for the youngest age group. For children seven and under who reported a search

strategy, speech appeared to be helpful, however, speech use was a liability for non-strategic searchers of the same age. Perhaps on this timed task, spending the time to say the numbers out loud for the young non-strategic children took too much away from their limited mental resources and detracted from performance. One of the benefits of using a strategy may be that it can free up other cognitive resources and make for more efficient processing. This is an intriguing finding and one in need of replication and further investigation given the small cell sizes involved here for this particular contrast. For the older age groups, speech did not interact with search strategy to predict performance. Speech did not matter for performance for the older children. This finding, that there are conditions under which private speech is and is not associated with improved task performance, is an important one for private speech researchers within the Vygotskian tradition to consider.

Finger placement/pointing increased in incidence from 12% at the age of 5 to about 25% for the older age groups. Pointing also interacted with strategic searching to predict performance. Across all ages, for non-strategic searchers, using one's finger as a placeholder was irrelevant for performance. However, for those who did report a systematic search strategy, pointing was linked with poorer performance. Pointing may get in the way of performance by being a waste of limited cognitive resources or by simply being an ineffective strategy for this task (perhaps one needs to see the gestalt of the number and not focus on one particular digit where the finger is placed). Thus, for young children engaged in a searching/matching task, what appears to be most important is using one's head (i.e., a strategy), then using one's mouth (private speech), and not using one's hands.

Although the present study had numerous methodological strengths, there are limitations here as well. In this case, the limitations follow from the use of archival test standardization data. First, it is important to keep in mind that only children's self-reported search strategies were examined. Although children's retrospective verbal reports of strategy use have been found to veridical for some tasks, under certain conditions (Bray et al., 1999; Robinson, 2001; Winsler & Naglieri, 2003), additional research using observational and/or performance (i.e., latency) measures of strategy use are clearly needed, especially given that the task used here was new. Thus, the results of the present investigation should be taken with some caution until children's verbal reports of strategy use on this particular task have been validated. It is possible and likely that other strategies were being used here and not reported. Somewhat helpful in this regard is the finding by Bray et al. (1999) that children appear to have a bias to be more likely to report using strategies that are positively associated with task performance than those not particularly helpful. If this is true, then at least it is unlikely that a very useful strategy was used often by the children and not reported. Further, the self-report measure used here could be reflecting changes in children's meta-cognitive awareness of strategy use (Karmiloff-Smith, 1992), rather than their strategy use per se.

A second limitation was the fact that youngsters were asked to report their search strategies after they had completed all items (rather than being asked immediately after each). It is possible that children used one strategy early on in the task and another one later and then did not recall all the strategies they had used, even though the entire task only lasted 5–8 min and children and the experimenter flipped through all the items during the strategy discussion. These limitations may have led to an underestimate the number and breadth of strategies used by the children.

A third potential limitation of the present study was the use of a task performance measure that involved speed/time. In the context of larger scale information searches (and mostly with adults), the information searching strategies people use to make a decision when under time constraints is sometimes different than those used when time is not a factor (Payne, Bettman, & Johnson, 1988). These investigators find individual differences in how much time matters for people's strategic



searching. The extent to which this may be an issue for children engaging in this simpler type of search task is unknown but it is suspected to be small since most children finished in time, and time was not particularly salient during the instructions or administration. Also, due to the nature of the original data collection in the context of test standardization, inter-rater reliability for the recording of children's strategy use was not available. Future investigations would benefit from including such information. A final limitation of the study was that only dichotomous strategy report/use (yes/no) at least once sometime during the multi-item task was available here. Clearly, it would be a good next step for research in this area to look microgenetically at children's strategy use and collect more information (both verbal and nonverbal) to determine the processes of single and multiple strategy selection, effectiveness, and change over time.

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