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Selective Attention and Active Engagement in Young Children

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During early development, significant changes occur in the neural regions that subserve attention and related skills. Although preschoolers typically have difficulty performing continuous performance tests, it is not clear if this is primarily due to an inability to selectively respond or an inability to maintain attention. A group of 52 children between 3.5 and 5.5 years of age performed 2 vigilance-type reaction time tasks. The tasks included short duration, continuously presented visual stimuli across several short blocks. Among the children under 4.5 years of age, 46% were unable to coordinate the necessary task demands, and those who could made significantly more omission errors than the older children. Active engagement was high during the reaction time tasks for all children. These results suggest that the skills necessary for vigilance tasks, particularly speeded response initiation and response selection, are still emerging during the preschool years but can be adequately measured after 4.5 years of age.

The significant increases in self-control and inhibitory control that are observed during infancy and early childhood appear to be important factors in the development of attention (Kopp, 1982; Vaughn, Kopp, & Krakow, 1984; Vaughn, Kopp, Krakow, Johnson, & Schwartz, 1986; Welsh and Pennington, 1988). These may reflect developmental changes in more complex social–behavioral and cognitive aspects of impulse control rather than the simple ability to inhibit motor movements (Olson, 1989). Improved ability to ignore potential distractors, decreased

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impulsivity, and decreased exploration have been hypothesized to play an important role in the young child's ability to selectively attend to the most important sources of information in the environment for maximal learning (Passler, Isaac, & Hynd, 1985). The developmental transition between 3 and 5 years appears to represent "a shift toward more voluntary or independent control" of attention (Ruff & Rothbart, 1996, p. 154). Attention becomes related to more planned, self-generated activity with objects, and attention is maintained to carry the activity to completion. From a neuropsychological perspective, the prefrontal cortex has been implicated in the inhibition of prepotent responses and the development of planned, goal-directed behavior (Diamond, 1991; Stuss & Benson, 1984). Changes in synaptic connectivity of the prefrontal cortex during this period have therefore been linked to these developmental changes (Diamond & Taylor, 1996; Huttenlocher & Dabholkar, 1997; Ruff & Rothbart, 1996; Welsh & Pennington, 1988).

Reaction time has traditionally been the most common single procedure for inferring attentional function (Plude, Enns, & Brodeur, 1994). Although reaction time tasks are used routinely in developmental studies of attention with older children and adults (for reviews, see Cooley & Morris, 1990; Enns, 1990), children under age 6 are seldom included. Reaction time tasks require participants to focus their attention in a situation that may not be intrinsically interesting. It is therefore often particularly difficult to distinguish between a young child's inability or unwillingness to perform this type of task. Reaction time tasks are hypothesized to require a substantial allocation of effort and will to sustain cognitive processing, consistent with what James (1890) described as "active attention." It has been suggested that especially for preschoolers, most sustained attention and behavior does not occur in situations requiring "active attention" (Choi & Anderson, 1991). However, increasing voluntary control of attention may be one factor that allows children to participate in reaction time tasks, particularly vigilance-type tasks (Ruff & Rothbart, 1996).

In one reaction time task, a picture of a rabbit remained on the computer screen until young children responded (Weissberg, Ruff, & Lawson, 1990). Although the 2.5-year-olds could perform the task, they required frequent reminders to respond. Reaction times decreased significantly with age, averaging approximately 3.8 sec for 2.5-year-olds and approximately 2.0 sec for 4.5-year-olds. Omission errors also decreased with age, averaging approximately 6.5% for 2.5-year-olds and less than 1% for 4.5-year-olds. In a subsequent study, focused attention was compared across tasks (Ruff, Capozzoli, & Weissberg, 1998). Focused attention during free play increased significantly, from 2.5 to 3.5 years, with little change after 3.5 years. In contrast, focused attention during the reaction time task was significantly higher among the 4.5-year-olds than the younger children. Although focused attention during free play was significantly correlated with focused attention during observation of a puppet show, neither measure was significantly correlated with focused attention or mean reaction time during the reaction time task. The authors suggested that as children mature, they are better able to sustain their attention in a variety of situations, and that focused attention in an unstructured situation may facilitate attentional control in a more structured situation.

Developmental changes in filtering abilities were studied in preschoolers (3.7–5.0 years), kindergartners, and second graders using a forced choice reaction time task similar to the Eriksen and Eriksen (1974) paradigm (Enns & Akhtar, 1989). Even the youngest participants made relatively few errors, although significantly more than the older children. The reaction time results demonstrated that the children were unable to avoid processing stimuli that flanked a target, even though the target appeared in a known location, whereas the older children were better able to inhibit processing these distractors, as evidenced by relatively faster reaction times. Younger children appeared to have significantly more difficulty with "attentional set," suggesting that the preparation to inhibit distractors was more effortful. Performance for all groups improved across trial blocks. The results suggested that significant improvements in selectivity with age were not due to improvements in planning or executing responses, but rather significant improvements in allocating resources appropriately to task components.

Vigilance tasks, such as the Continuous Performance Test (CPT), are commonly used for assessing attention deficits in school-age children. A continuous stream of briefly presented visual or auditory stimuli is presented, and the child is told to respond only to a target stimulus that occurs infrequently. Vigilance tasks therefore represent a special case of selective attention where attention is required over an extended period of time (Cooley & Morris, 1990).

Although the standard CPT includes letter stimuli, it is more appropriate to use appealing, nonlinguistic stimuli with preschoolers. Using a modified version of the visual CPT, pictures were briefly presented for 750 msec, with an interstimulus interval of 1,500 msec (Corkum, Byrne, & Ellsworth, 1995). The task lasted for 9 min. Half of the children under the age of 4 were unable to complete the task, either because they could not coordinate all of the task demands or were only able to do so for a brief period of time. The 3-year-olds who were able to complete the task had a significantly higher omission rate (approximately 40%) than the 4- and 5-year-olds (22% and 10%, respectively), and the frequency of misses increased over trials. The 3-year-olds also made more false alarm errors (27%) than the 4- and 5-year-olds (6% and 4%, respectively). The 3-year-olds spent significantly more time looking away from the computer screen (27%) than the 4- and 5-year-olds (14% and 8%, respectively). Similar results were also reported in an unpublished study using a similar type of paradigm (Prather, Sarmento, & Alexander, 1995). In another CPT study of preschoolers that used letter stimuli, 65% of the children under the age of 4 were unable to complete the task, whereas 29% of the children between 4 and 4.5 years old failed to complete the task (Levy, 1980). The 3-year-olds who completed the task made more omissions (approximately 50%) and false alarms (approximately 67%) than the 4- and 5-year-olds

(19% and 7%; 18% and 11%, respectively). The stimuli were longer in duration (2,000 msec) than those used in the Corkum, Byrne, and Ellsworth (1995) study, but the task lasted only 4.7 min. Poorer performance among the young children may have been due to the longer intervals between the onset of stimuli (leading to more off-task behavior). Alternatively, the use of letter stimuli may be more difficult for young children to distinguish, leading to the inability to complete the task and more commission errors.

This study utilized three reaction time tasks: a simple reaction time task and two modified vigilance tasks. All tasks included continuously presented visual stimuli in relatively short blocks. The simple reaction time task was included as a warm-up task and also to verify that performance on the selective attention reaction time tasks was or was not due to difficulty with simple response demands. The other two tasks were based on the visual oddball paradigm that has been used with school-age children (Courchesne, 1977, 1978). This type of task was chosen because the learning environment typically requires children to be ready to detect changes that occur at random time intervals (Parasuraman, Warm, & See, 1998). When participants are required to monitor a succession of stimuli for a specific target, the stimulus duration time and the interstimulus interval affect error rates (omissions and false alarms) and reaction time (Chee, Logan, Schachar, Lindsay, & Wachsmuth, 1989). The tasks in this study used a brief stimulus presentation (500 msec) and a relatively short interstimulus interval (500 msec). These parameters were chosen to minimize the likelihood that attention would wander between trials while allowing the children adequate time to process each stimulus before the next stimulus appeared. The two selective attention tasks differed in terms of presence or absence of distractors and picture type to explore issues related to sustained attention, inhibitory control, and filtering in preschoolers.

Based on the existing literature, younger children might be expected to make more commission or omission errors on these modified vigilance tasks than older children. Younger children might have difficulty maintaining the task instructions in working memory and related difficulties with response inhibition, particularly in the presence of distractors. Younger children typically take longer to execute a response, and this might lead to increased omission errors, particularly if the target stimuli occur infrequently. Reduced focused attention, reflected in increased time spent looking away from the screen, might also lead to poorer performance and increased response times. However, in contrast to studies using a CPT, younger children might perform better on a shorter, blocked trial reaction time task due to difficulty maintaining their attention over a long period of time. It was predicted that there would be significant changes in active engagement with age. This study extends previous work by requiring the children to constantly monitor the ongoing stimuli to engage the appropriate response.

METHOD

Participants

The participants were 52 children, ranging in age from 3.5 to 5.5 years ($M = 4.48$, $SD = .58$). There were 23 boys and 29 girls; 45 of the participants were right-handed. Participants were recruited from three local day care centers and two local preschools. Parents of the participants completed a brief medical history questionnaire and a brief demographics questionnaire. Based on their responses, all participants in this study had a normal birth history and were free of medical, cognitive, language, sensory, and motor impairments. Approximately 61% of the participants had at least one parent with a college degree; 25% of the participants were African American, 69% were White, and 6% classified their ethnic status in neither category. The mean standard score on the Visual–Motor Integration Test (VMI; Beery, 1997) for this sample was 105.1 (SD =17.5), and the mean standard score on the Peabody Picture Vocabulary Test–Revised (PPVT–R; Dunn & Dunn, 1981) was 102.4 (SD = 16.8). The age-referenced standard scores for both tests have a mean of 100 and a standard deviation of 15.

Procedure

Children were tested individually in a room that was separate from their regular classroom at their daycare center. Each child sat in a child-size chair at a child-size table. All children were videotaped during the testing. The video camera was placed on a tripod facing the child so as not to interfere with the testing. Completion of the test battery typically required three 30-min testing sessions, completed on separate days within the span of 1 week. The order of the tests across these sessions was as follows: VMI, PPVT–R, free play, simple reaction time task, selection/distractor task, raisin delay task, nesting cups task, and picture selection task. The results from the free play, raisin delay, and nesting cups tasks were presented previously (Akshoomoff, 1998; Thurmond, 1997) and will not be discussed here. Each child was given a sticker at the completion of each task to maintain interest and motivation. The examiners were senior undergraduate and graduate students who were not known to the participants.

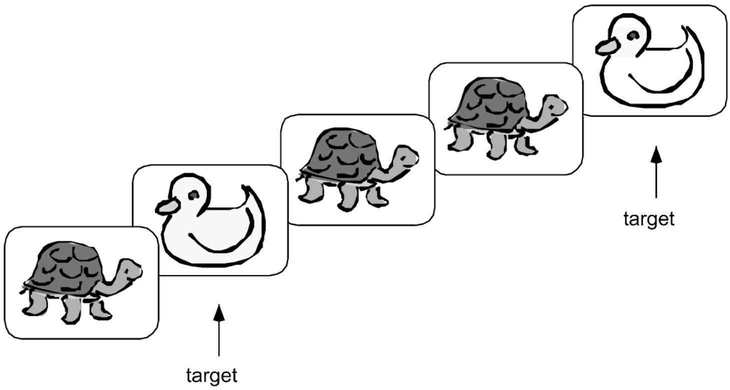
The three reaction time tasks were presented on a Macintosh PowerBook 5300c portable computer using the PsyScope software program (Cohen, MacWhinney, Flatt, & Provost, 1993). Each child was positioned in front of the computer so that his or her eyes were approximately 38 cm from the screen. The PsyScope button box was attached to the computer and was used for recording the children's responses and reaction time information. The button box had three small square response buttons (green, yellow, and red), with a corresponding colored light below. Computerized feedback consisted of a beep for correct responses and a negative tone for incorrect responses. In each task, the child was told to press the middle (yellow) button; the adjacent yellow light stayed on throughout the task as a cue regarding which button to press. At the end of each block of trials in each task, the child was presented with a colorful picture on the screen and was given a short break. The examiner sat next to the child during all of the test procedures.

In the simple reaction time task, children were told, “Every time you see a duck, press this button [middle button on button box] as quickly as you can. Always use this finger [point to index finger on dominant hand.]” Each child was given a block of 9 practice trials followed by a block of 20 test trials. The target stimulus (the duck depicted in Figure 1) remained on the screen for 500 msec, followed by a 1,500-, 2,000-, or 2,500-msec interstimulus interval (ISI). This task was intended to be a “warm-up” task to introduce the participants to the reaction time format. This task did not require a selection (participants were to respond to every stimulus) and used longer and variable ISIs than the other two reaction time tasks.

The picture selection task required the child to respond to an infrequent ($p = .25$) target stimulus (a color drawing of a duck; see Figure 1). The frequent ($p = .75$) nontarget stimulus was a color drawing of a turtle. Children were told, “When I start this game, you need to watch the computer screen. Every time you see a duck, you push *this* button [examiner pointed to middle button on button box] as quickly as you can. Always use this finger [examiner pointed to index finger on dominant hand.] Don’t push the button if you see something else. Try your best.” Each stimulus remained on the screen for 500-msec, followed by a 500-msec ISI. Each child was given a block of 12 practice trials. Following the practice trials, each child was given 4 blocks of 24 trials each. There were thus a total of 96 stimuli (25% targets and 75% nontargets). This task took approximately 5 min to complete.

The stimuli in the selection/distractor task consisted of an infrequent ($p = .25$) target stimulus (a circle; see Figure 1) and a frequent ($p = .75$) nontarget stimulus (a square); half the stimuli were closely flanked by distractor stimuli (crosses). These stimuli are similar to those used in a study by Enns and Akhtar (1988), where young children were presented with a speeded, two-alternative choice filtering task. Each stimulus remained on the screen for 500-msec, followed by a 500-msec ISI. A block of 18 practice trials was first presented. Each child was told, “When I start this game, you need to watch the computer screen. Every time you see a circle in the *middle*, you push *this* button [examiner pointed to middle button on button box] as quickly as you can. Always use this finger [examiner pointed to index finger on dominant hand.] Don’t push the button if you see something else. Try your best.” If the child did not correctly identify three of the six targets and responded to more than five of the nontarget stimuli, the instructions and the practice trials were repeated. Following the practice trials, each child was given four blocks of 24 trials each. There were a total of 96 stimuli (12 targets, 12 targets flanked by crosses, 36 nontargets alone, and 36 nontargets flanked by crosses). This task took approximately 5 min to complete.

A. Picture Selection Task



B. Selection/Distractor Task

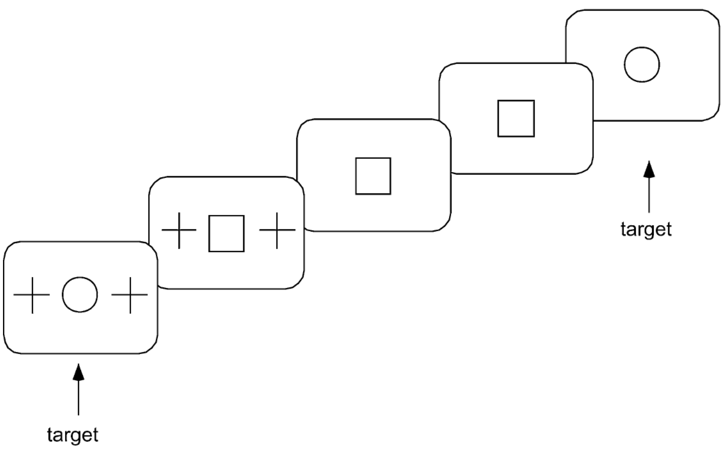


FIGURE 1 Sample sequence of the stimuli used in the selective attention tasks. Arrows indicate target stimuli. Each stimulus measured approximately 3 × 3 cm.

Data Coding and Analyses

The median reaction time of each individual's set of reaction times was calculated for all target detection trials in the three reaction time tasks. The median reaction time was chosen to avoid undue influence of extreme values, which may be more common in young children's data. The percentage of target detections ("*hits*") and false alarms (where applicable) were calculated based on the number of possible occurrences (e.g., percent responses to target stimuli out of 24 possibilities during picture selection). Performance criteria for inclusion in the study were at least 50% hits and less than 20% false alarms in both the picture selection and selection/distractor tasks. To assess the possibility of changes in performance due to fatigue or practice in the picture selection and selection/distractor tasks, the first two blocks of trials were combined ("Block 1") and compared to the third and fourth blocks ("Block 2"). Blocks were combined due to the limited number of trials in each block. Percent hits and median reaction time were then computed for each block in each task. The median reaction time was used rather than the mean to avoid undue influence of extreme values, which were fairly common across participants, particularly among the younger children.

The videotapes were coded for the percentage of time across the trials that the child was looking away from the computer screen, and for the percentage of time spent in off-task behavior while the child was looking at the screen. The three reaction time tasks were coded by a total of three coders. All coders were naive to the study hypotheses and the age of the children. Off-task behavior was defined as talking (to one's self or to the examiner), laughing, stretching, or repetitive movements while looking at the screen. Data from 3 children were not obtained because it was not possible to see their faces during part of the videotape during the selection/distractor task and the picture selection task. Interrater reliability was calculated using Pearson product-moment correlations between durations recorded independently by two observers across data from 10 participants. "Active engagement" was defined as the percentage of time not spent looking away from the screen and not spent in off-task behavior. For the simple reaction time task, interrater agreement for the percentage of time in active engagement was .91. For the picture selection task, interrater agreement for the percentage of time in active engagement was .92. For the selection/distractor task, interrater agreement for the percentage of time in active engagement was .97. The raters did not differ significantly in any comparison in terms of the percentage of time spent in active engagement (t tests for these three values: ps > .05).

RESULTS

Overall performance in the simple reaction time task for the 52 participants was quite good in terms of hit rate (M = 92.7%, SD = 9.9) and in terms of median reaction time (M = 588.3 msec, SD = 185.69).

Data from 11 children (5 boys and 6 girls) between 3.58 and 4.33 years of age and one 4.5-year-old girl were eliminated from further analyses because they failed to meet performance criteria on the selection/distractor task. These 12 children had a significantly reduced hit rate on the simple reaction time task than the 13 children under the age of 4.5 whose data were included in the analyses, separate variance *t* test: $t(14.7) = 2.17$, $p < .05$, but did not differ in terms of median reaction time on this task, $t(15.7) = -.27$, *ns*. Data from one additional child (a boy 5.42 years old) was also excluded because he made more than 20% false alarm errors in both the selection/distractor and the picture selection tasks.

The characteristics of the 12 children who were excluded (3.58–4.5 years) were compared with the characteristics of the children included in the 13 children under 4.5 years of age who met the inclusionary criteria. Chi-square analyses revealed that these groups were not significantly different in terms of the relative proportions of girls and boys or race (*p*s > .40). *T* tests revealed that these groups were not significantly different in terms of their scores on the VMI ($M = 99.58$ vs. $M = 106.54$) or the PPVT–R ($M = 94.92$ vs. $M = 101.46$).

The remaining 39 participants were 20 boys and 19 girls between the ages of 3.58 and 5.5 years. Prior studies and pilot testing suggested that by 4.5 years of age, most children are able to coordinate the task demands for a selective attention reaction time task, but performance continues to improve past age 5. To determine the effect of age on performance on the two selective attention tasks, the children were therefore divided into three age groups (see Table 1).

On the simple reaction time task, the three age groups did not differ from each other in terms of the percentage of hits, $M = 93.08$, 95.33, and 95.91, respectively; $F(2, 36) = .73$, *ns*. However, the three age groups did differ in terms of median reaction time, $F(2, 36) = 3.81$, $p < .05$. Tukey post hoc tests revealed that the children in the youngest age group ($M = 661.15$, $SD = 248.12$) were significantly slower than the children in the oldest age group ($M = 458.77$, $SD = 66.64$). The median reaction time for the children in the middle age group ($M = 537.93$, $SD = 171.37$) was not significantly different from the other two groups.

TABLE 1
Characteristics of the Final Sample of Participants in the Three Age Groups

	Age 3.6–4.4[a]	*Age 4.5–4.9*[b]	*Age 5.0–5.5*[c]
Mean age (years)	3.96 (.26)	4.74 (.15)	5.22 (.19)
Sex	8 girls, 5 boys	8 girls, 7 boys	6 girls, 5 boys
Race	7 White, 5 African American, 1 Other	13 White, 2 African American	10 White, 1 Other
Handedness	11 right, 2 left	14 right, 1 left	8 right, 3 left
Mean PPVT-R scores	100.23 (17.54)	103.13 (14.45)	113.36 (14.04)
Mean VMI scores	106.00 (15.80)	103.53 (16.97)	113.82 (20.18)

Note. Standard deviations are in parentheses. PPVT–R = Peabody Picture Vocabulary Test–Revised; VMI = Visual–Motor Integration Test.

[a]$n = 13$. [b]$n = 15$. [c]$n = 11$.

Selective Attention Tasks

False alarm errors for the two selective attention tasks were positively skewed due to the large proportion of children with fewer than 10% false alarm errors (i.e., less than 7 out of a total 96 possible incorrect responses). The percentage of false alarm errors was similar across the two tasks (picture selection: M = 3.5, SD =3.89; selection–distractor: M = 3.3, SD = 3.12). False alarm errors were not different across the age groups in picture selection, $F(2, 36) = .71$, *ns*, or selection/distractor, $F(2, 36) = .26$, *ns* tasks.

Separate repeated measures analyses of variance (ANOVAs) were computed for the picture selection and selection/distractor tasks with Block as the within-subjects factor and two between-subjects factors (Age, Group, and Sex) for both percent hits and median reaction time. No significant main effects or interactions were found for Sex or Block in either ANOVA. The analyses were then computed collapsed across Sex and Block.

In the picture selection task, the age groups did not significantly differ in their hit rate, $F(2, 36) = 2.36$, but were significantly different in terms of median reaction time, $F(2, 36) = 3.44$, $p < .05$; see Figures 2 and 3). Post hoc Tukey tests revealed that the children in the youngest age group were significantly slower than the children in the oldest age group ($p < .05$). There was a significant correlation between percent hits and median reaction time across all participants, $r(39) = -.44$, $p < .01$, indicating that those children with the fastest reaction times tended to make the most hits.

To assess the effect of the simultaneously presented irrelevant stimuli in the selection/distractor task, responses to the target stimuli with and without the

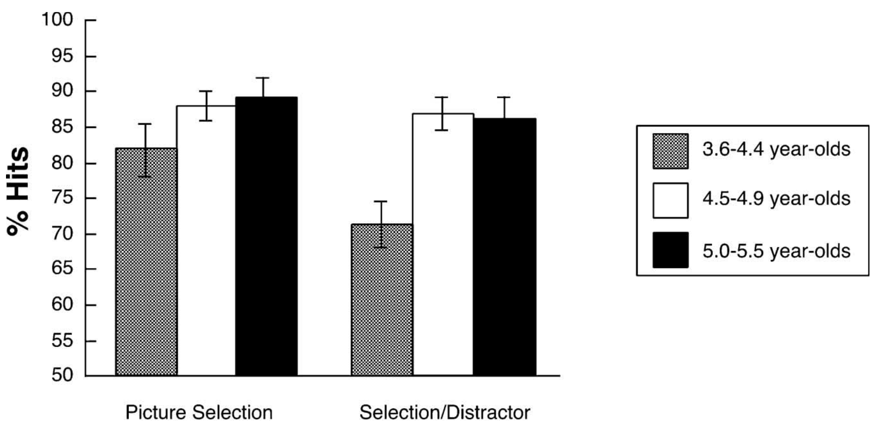


FIGURE 2 Mean percent hits. Error bars represent standard error of the mean.

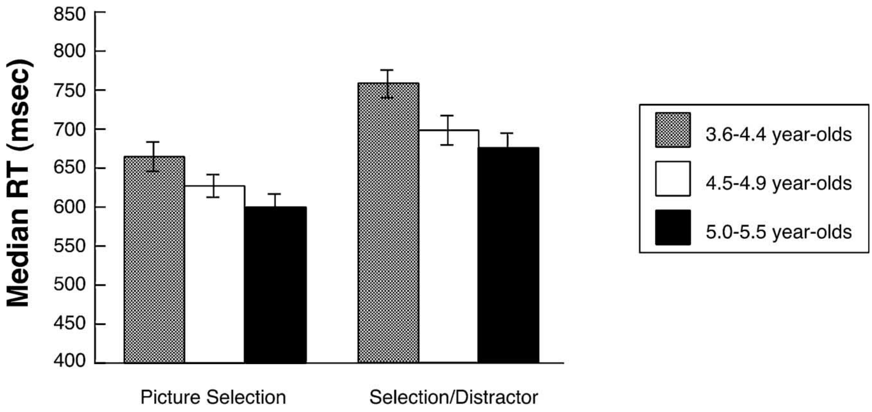


FIGURE 3 Mean median reaction time. Error bars represent standard error of the mean.

crosses were compared. A repeated measures ANOVA revealed that the three age groups were significantly different in terms of hit rate, $F(2, 36) = 9.62$, $p < .001$ (see Figure 2). Post hoc Tukey tests revealed that the children in the youngest age group had a significantly reduced hit rate compared to the children in other age groups (*p*s < .05). Overall, the participants had fewer hits to the targets that were surrounded by crosses ($M = 77.92$, $SD = 17.55$) than those without crosses ($M = 84.75$, $SD = 13.41$). This difference approached significance, $F(1, 36) = 3.90$, $p = .056$. There was not a significant Age × Stimulus interaction, $F(2, 36) = 2.92$, *ns*. A repeated-measures analysis of variance revealed that the three age groups were also significantly different in terms of median reaction time, $F(2, 36) = 8.51$, $p < .001$ (see Figure 3). Post hoc Tukey tests revealed that the children in the youngest age group had significantly slower reaction times compared to the children in other age groups (*p*s < .05). Median reaction times were not significantly slower to targets with crosses ($M = 714.51$ msec, $SD = 79.50$) than those without crosses, ($M = 698.20$, $SD = 85.98$) $F(1, 36) = 1.85$, *ns*, and there was not a significant Age × Stimulus interaction, $F(2, 36) = 1.42$, *ns*.

During the picture selection task, there were no significant differences in the percentage of time spent in active engagement across the three age groups, $F(2, 35) = 1.94$, *ns*, (see Figure 4). The same was true during the selection–distractor task, $F(2, 36) = 1.27$, *ns*, (see Figure 4). Across the group of participants as a whole, the percentage of time spent in active engagement during the picture selection task was significantly correlated with the percentage of hits ($r = .47$, $p < .001$) but not median reaction time ($r = .007$). During the selection/distractor task, active engagement was significantly correlated with the percentage of hits ($r = .39$, $p < .05$) and negatively correlated with median reaction time ($r = -.34$, $p < .05$).

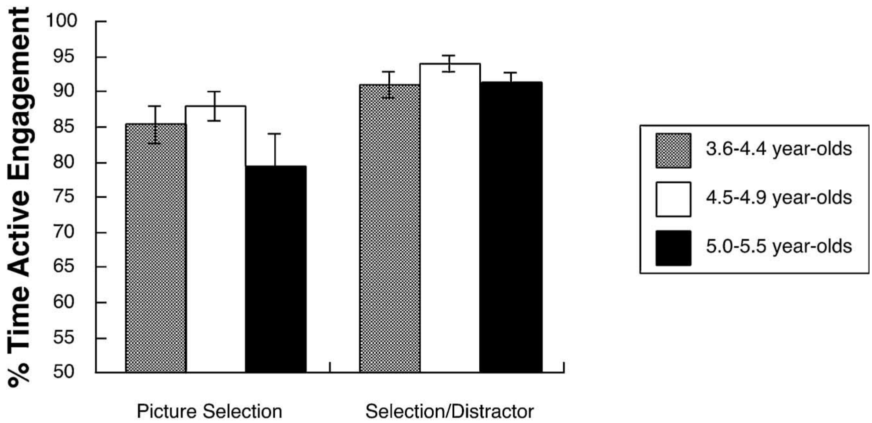


FIGURE 4 Mean percent time spent in active engagement. Error bars represent standard error of the mean.

DISCUSSION

The results of this study demonstrate that some young children can quickly and accurately respond to an infrequent target that occurs within a continuous stream of visual stimuli. However, 11 of the original 24 children between 3.5 and 4.5 years of age were unable to meet criteria for the two selective attention tasks and had significantly fewer target detections in the simple reaction time task than the other children. Failure to meet criteria was generally due to a reduced number of hits (i.e., increased omission errors) rather than excessive false alarm errors. It was expected that it would be more difficult for the youngest children in this study to put together the steps necessary for a reaction time task (watching the screen, waiting for the target stimulus to appear, pressing the response button as quickly as possible when the target appears, and continuing to watch the screen). It is therefore not surprising that the younger children who were unable to meet criteria for the two selective attention tasks made more omissions when responding to a single, rapidly presented target.

Overall median response times were relatively rapid (between 600 and 750 msec on average). This is in contrast to previous studies with preschoolers that required the child to respond to every stimulus (Ruff et al. 1998; Weissberg et al., 1990) or to make a response decision for each stimulus (Enns & Akhtar, 1989). In those studies, each stimulus remained on the screen until the child responded, and mean reaction times ranged from 1,200 to 1,900 msec. In this study, there was a continuous stream of rapidly presented stimuli and the target appeared only 25% of the time. The percentage of omission errors for children over 4.5 years of age was comparable to those reported in CPT studies (Corkum et al., 1995; Levy, 1980; Prather et al., 1995), but the percentage of commission errors was less.

Active engagement was very high among the participants in the reaction time tasks, regardless of age. The high percentage of active engagement across age groups indicates that young children who are capable of performing this type of selective reaction time task are those who spend a high percentage of time monitoring the screen in order to quickly respond to the target stimuli. This is consistent with Ruff and Rothbart's (1996) hypothesis that there is a significant shift around 4 years of age in the child's ability to voluntarily direct attention. Whereas some children under 4 years of age can focus on a stream of visual stimuli for at least 1 min and attempt to perform a vigilance type task, performance is typically not proficient until a later age. A previous CPT study with 3-, 4-, and 5-year-olds found significant age-related decreases in time spent looking away from the screen (Corkum et al., 1995). This suggests that if the task continues for a long period of time (e.g., 9 min), younger children may spend more and more time looking away from the screen. Increased off-task behavior with longer task duration may also lead to increased commission errors.

The children in this study were more likely to make errors of omission than commission. This was also true in other studies in my laboratory using similar types of visual and auditory paradigms with young children (Bivens, 1998; Cukrowicz, 1999). Given the levels of active engagement during the selective attention tasks, other factors must have interfered with their ability to rapidly respond to the target stimuli. Improvements in response speed with age appear to be primarily due to changes in central processing speed, as well as changes in motor execution time (Hale, 1990; Kail, 1986; Karrer, 1986). That is, compared to adolescents and adults, children appear to be slower in response initiation and, to a lesser degree, motor execution. Children are also slower in response selection. Although the picture selection and selection/distractor tasks did not require response selection, it may have taken the younger children longer to decide whether to respond or not to respond (the "go/no-go" decision). It is therefore possible that the younger children may have sometimes failed to respond by the time another stimulus appeared, despite having made a decision to do so—the so-called refractory effect (Welford, 1952). Further studies are needed to determine to what degree this may be more of an issue for younger children compared to previous studies that have included school-age children (Hale, 1990; Kail, 1986; Karrer, 1986) or if this reflects the amount of time required for children to make a response decision.

The limited number of false alarm errors suggests that under these stimulus conditions, young children may be fairly conservative in their response characteristics. Additional studies are needed to determine what circumstances lead to more impulsive errors, as is more typical of children with attention deficit hyperactivity disorder (Chee et al., 1989), and is more typical among young children in (long-duration) CPT tasks. In an event-related brain potential study, the posterior positivity associated with correctly rejected, task-irrelevant visual stimuli was significantly larger in 5-year-olds than 9-year-olds (Wijker, 1991, cited in van der Molen & Molenaar, 1994). This processing difference was found despite the absence of an age-related change in the proportion of commission errors and suggests that selection occurred at a later level of stimulus analysis for the younger children than the older children. This functional brain imaging technique could serve as a useful indicator in future studies of where the child's attention is focused in conjunction with their behavioral task performance, and perhaps help us to better understand the processes involved in the development of selective attention.

Reaction times were slower and children made more omission errors in the selection/distractor task compared to the picture selection task, despite the fact that active engagement was high in both tasks. Although these tasks used the same parameters in terms of stimulus duration (500 msec) and interstimulus intervals (500 msec), they differed in several respects, making any direct comparisons across tasks problematic. First, they differed with respect to the presence or absence of simultaneously presented distractors. The overall poorer hit rate in the selection/distractor task appears to have been due to significantly fewer responses to the target stimuli that were flanked by crosses, although median reaction times were not significantly slower to targets with crosses than those without crosses. Second, children were given the picture selection task after the selection/distractor task, leading to the possibility that relatively better performance in the picture selection task was due to a "practice effect." Children were more likely to comment that the selection/distractor task was "too fast." Perhaps they did this less often in the picture selection task because they had become familiar with the task demands that were common to both tasks.

A third area is the nature of the stimulus types used in these two tasks. The stimuli in the selection/distractor task were black outlines of shapes, whereas the stimuli in the picture selection task were colored drawings of familiar animals. Poorer performance in the selection–distractor task compared to the picture selection task may have reflected differences in the discriminability, meaningfulness, and familiarity of the stimuli. These stimuli also differed in terms of the absence or presence of a solid color and representation of animacy. This may have made the stimuli in the selection/distractor task less interesting for the younger children to attend to than those in the picture selection task. Although the relationship between selective attention and interest has not been adequately studied, recent studies suggest that interest does have a significant impact on selective attention in young children (Renninger, 1990; Renninger & Wozniak, 1985). It is possible that interest has a greater impact on younger children's performance compared to older children. Few studies have addressed this hypothesis specifically. This may also relate to the hypothesis that improvements in attention beginning in the preschool period reflect a change in the child's ability to attend to tasks that are not as intrinsically rewarding (Ruff & Rothbart, 1996).

A vigilance network in the right prefrontal cortex has been hypothesized to be important for accurate and rapid responses to infrequent stimuli (Posner & Petersen, 1990). Functional neuroimaging studies and studies with lesion patients have revealed that in addition to prefrontal cortex, the parietal cortex, basal ganglia, and the cerebellum are also involved in these types of selective attention tasks (Akshoomoff & Courchesne, 1992, 1994; Allen, Buxton, Wong, & Courchesne, 1997; Coull & Nobre, 1998; Cummings, 1995; Le, Pardo, & Hu, 1998; Rosen et al., 1999; Townsend & Courchesne, 1994; Townsend, Courchesne, & Egaas, 1996; Townsend et al., 1999). The skills employed during less structured situations, where the child is able to choose what he or she attends to ("passive attention"), may be governed by a slightly different network that matures earlier but is nonetheless important for the development of active attention.

The results of this study suggest that when the task is relatively brief, young children can remain focused on the task and respond relatively quickly but have more difficulty doing this consistently, and thus the necessary skills for this type of vigilance task are emerging between the ages of 3.5 and 4.5 years. It is likely that children in this age range who are capable of adequately performing this type of task are not necessarily representative of children their same age. Additional studies are needed to determine how experimental manipulations such as increasing the interstimulus interval and manipulating stimulus probabilities may lead to improved performance in young children. More research is also needed to determine how the performance of young children during reaction time tasks is related to performance on other types of attention tasks, more general response inhibition problems, and potential school-related difficulties. Of interest is how data from "laboratory tasks," such as the ones employed in the present study, may contribute to clinical assessments and educational considerations for young children in conjunction with more standard tools, such as parental questionnaires and behavioral observations.

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