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Assessing selective sustained attention in 3- to 5-year-old children: Evidence from a new paradigm

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ABSTRACT

Selective sustained attention (SSA) is crucial for higher order cognition. Factors promoting SSA are described as exogenous or endogenous. However, there is little research specifying how these factors interact during development, due largely to the paucity of developmentally appropriate paradigms. We report findings from a novel paradigm designed to investigate SSA in preschoolers. The findings indicate that this task (a) has good psychometric and parametric properties and (b) allows investigation of exogenous and endogenous factors within the same task, making it possible to attribute changes in performance to different mechanisms of attentional control rather than to differences in engagement in different tasks.

Introduction

William James famously wrote, "Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects" (James, 1890, pp. 403–404). Subsequent research has qualified James's claim by suggesting that attention is a multifaceted construct that serves several different functions. Among the most commonly distinguished functions are *alerting* (achieving high sensitivity to incoming stimuli), *orienting* (selecting information from sensory input), and *maintaining* (sustaining attention, especially in the face of distracting stimuli) (Colombo & Cheatham, 2006; Kahneman, 1973; Posner & Petersen, 1990; Posner & Rothbart, 2007). However, all of these functions share the common theme originally enunciated by

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James of one potential object of attention "taking possession of the mind" at the expense of other simultaneously possible objects. That is, one of the central features of any theory or description of attention is that attention is *selective*.

Although the process of selection is still not fully understood (e.g., Anderson, 2011; Pashler, Johnston, & Ruthruff, 2001), many psychologists have suggested that the factors that promote selection can be described as either *exogenous* or *endogenous*. Exogenous factors are the characteristics of the stimuli (e.g., contrast, brightness, motion); they are often described in terms of the degree to which a stimulus is "salient." Endogenous factors, by contrast, relate to the voluntary control of the organism over attention (e.g., goal-related actions). In newborns and very young infants, selection is typically described as stimulus driven or automatic. In other words, the locus of attention early in life is determined largely by the physical properties of a stimulus such as frequency and duration for auditory stimuli and intensity, degree of curvature, and brightness for visual stimuli (for reviews, see Bornstein, 1990; Ruff & Rothbart, 2001).

Over the course of development, endogenous factors come to play a larger role in determining the locus of attention (Colombo & Cheatham, 2006; Diamond, 2006; Oakes, Kannass, & Shaddy, 2002; Ruff & Rothbart, 2001). Endogenous factors are those cognitive processes that allow the organism to voluntarily control the locus of its attention. In particular, working memory has been suggested to be a key factor because active maintenance of a goal representation is required in order to organize behavior to achieve the goal (Colombo & Cheatham, 2006; Kane & Engle, 2002). The increased contribution of endogenous factors has been linked to the maturation of the prefrontal cortex (PFC) and efficiency of dopaminergic transmission in the PFC (Casey, Giedd, & Thomas, 2000; Diamond, Briand, Fossella, & Gehlbach, 2004; Posner & Rothbart, 2007).

Once a target has been selected, task-appropriate behavior (e.g., in learning or continuous tasks) often requires that attention on that target be sustained. As with selection, exogenous factors are thought to play the most important role in the maintenance of attention early in development. For example, once infants have oriented toward a visual stimulus, the duration of their sustained attention (as measured by heartbeat deceleration) depends on factors such as stimulus novelty and complexity; sustained attention is at its maximum when objects are novel, and termination of sustained attention is particularly likely if there is competition from another novel object or event (e.g., Casey & Richards, 1988; Richards, 1987). Over the course of development, endogenous factors come to play a more important role in sustaining attention, just as they do in selecting the locus of attention. In particular, sustaining attention on a target often depends heavily on the ability to inhibit orientation to distracters (Colombo & Cheatham, 2006; Ruff & Rothbart, 2001). Inhibition, like goal maintenance, is commonly linked to regions of the PFC and often invoked in theoretical accounts of executive function (e.g., Braver, Barch, Gray, Molfese, & Snyder, 2001; Diamond et al., 2004).

Prior research presents a clear picture of the increasing contribution of endogenous factors, such as maintenance of goal representations and response inhibition, to selective sustained attention through infancy and early childhood. However, quantifying the contributions of exogenous and endogenous factors is difficult. This is because most of the tasks used to assess selective sustained attention in infants and children allow for the manipulation of exogenous factors but are less amenable to manipulations aimed at endogenous factors. For example, selective sustained attention during infancy is often assessed via gaze fixation and heartbeat in response to visually presented stimuli. Studies with infants and older children often rely on elaborate coding schemes to characterize the attentional state of a participant in free play settings. The determination that a child is in a state of selective sustained attention can be made, for example, on the basis of a child's direction of gaze and behavior, including "intent facial expression" or "minimal extraneous bodily activity" (Choudhury & Gorman, 2000; Oakes et al., 2002; Ruff & Capozzoli, 2003; Ruff & Rothbart, 2001; Tellinghuisen, Oakes, & Tjebkes, 1999). However, these gaze- and play-based experiments primarily allow for the manipulation of the exogenous characteristics of the objects with which infants and children are presented. These experiments have been tremendously informative in indicating which features of visual stimuli capture attention (e.g., Casey & Richards, 1988), but they provide limited options for manipulating or assessing endogenous factors. The fact that methodologies appropriate for use with infants and children are primarily sensitive to exogenous factors is problematic; although endogenous factors are often claimed to become increasingly more important over the course of development, methodological limitations prevent researchers from seeing how these factors interact in the same task.

In adults, the contribution of both exogenous and endogenous factors to selective sustained attention can be assessed in the same task, often via the Continuous Performance Test (CPT; Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956). This task was first developed as a screening tool for brain damage but is widely used today to examine selective sustained attention in neurotypical adults (e.g., Davies & Parasuraman, 1982; Nuechterlein, Parasuraman, & Jiang, 1983), typically developing children (e.g., Akshoomoff, 2002; Corkum, Byrne, & Ellsworth, 1995), and patients with attention deficit/hyperactivity disorder (ADHD) (e.g., Barkley, 1997; Kerns & Rondeau, 1998) or schizophrenia (e.g., Cornblatt & Keilp, 1994; Nuechterlein & Dawson, 1984). During the CPT, participants are presented with a continuous stream of stimuli (visual or auditory) consisting of infrequently appearing targets in a string of nontargets (usually numbers or letters). Participants are asked to respond to targets, usually via a button press, and withhold responses to nontargets. Performance on the task is measured in terms of commission errors (false alarms), omission errors (misses), reaction time, and signal detection indexes d' (sensitivity) and β (response criterion).

Both exogenous factors (e.g., ratio of targets to nontargets, presentation rate, modality) and endogenous factors (e.g., clinical symptoms, number of targets the participant is required to represent) affect performance on the CPT, and it has been used to assess the contribution of both kinds of factors to attention *within the same task* (for extensive reviews, see Ballard, 1996; Riccio, Reynolds, & Lowe, 2001). Standard versions of the CPT have been successfully used with children from approximately 5 or 6 years of age (e.g., Edley & Knopf, 1987; Gordon, Thomason, & Cooper, 1990). However, the task is ill-suited for use with younger children, primarily because of the long task duration and children's potential unfamiliarity with the letters and numbers often used as targets in the task. Several investigators have attempted to adapt the CPT for use with younger children, for example, by slowing down the rate of stimulus presentation, using targets familiar to the child, and reducing overall task duration. However, even with such alterations, it is common for researchers to report that nearly half of the children below 4.5 years of age do not reach performance criteria necessary for inclusion in data analyses (e.g., Akshoomoff, 2002; Chatham, Frank, & Munakata, 2009; Corkum et al., 1995).

Our goal in the current research was to develop a new developmentally appropriate paradigm (not based on the CPT) for assessment of sustained selective attention in the visual domain. To extend beyond prior research, such a task needs to investigate the contribution of exogenous and endogenous factors contributing to selective sustained attention within the same task. Assessing the contribution of these factors in different tasks presents interpretational difficulties. For example, in studies using free play sessions, children are often seen to sustain attention longer than in studies using the CPT (e.g., Annett, Bender, & Gordon, 2007; Kerns & Rondeau, 1998; Ruff & Lawson, 1990). This difference may be due to the greater difficulty in relying on endogenous factors (e.g., working memory) in the CPT in contrast to the exogenous factors that drive attention in free play sessions. Alternatively, this difference may simply be due to differences in the degree to which the task itself engages children (Ruff & Rothbart, 2001). If both exogenous and endogenous factors can be assessed within the same paradigm, task-specific explanations (e.g., the child's level of engagement in different tasks) can no longer account for differences in performance. In particular, there is a need to assess the contributions of these factors to selective sustained attention for children in the preschool age range. As indicated by the above review of the methods used to assess development of selective sustained attention, preschoolers are in a measurement gap—too old for looking-based and heart rate measures, but too young to successfully perform the CPT. To achieve these goals, we have developed the Track-It task, designed to assess selective sustained attention in preschool-age children.

The Track-It task is reminiscent of the Multiple Object Tracking (MOT) task used with adults to study properties of visual attention (Bahrami, 2003; Pylyshyn & Storm, 1988; Yantis, 1992). In the MOT task, participants are asked to visually track several identical target objects moving along random trajectories among a larger set of identical objects, also moving along random trajectories. In this paradigm, target objects are distinct only at the beginning of each trial (e.g., all target objects may pulsate for a brief period of time at the onset of each trial [but see Makovski & Jiang, 2009]); however, adult participants (often to their own surprise) are capable of tracking four targets in the field of eight distracters with accuracy approaching 90% (Pylyshyn & Storm, 1988). This paradigm has been successfully used with adults to investigate properties of object-based attention (Pylyshyn & Storm, 1988; Scholl, Pylyshyn, & Feldman, 2001), change detection (Bahrami, 2003), and visual working memory (Makovski & Jiang, 2008). However, pilot testing suggested that the MOT task is prohibitively complex for young children.

In the Track-It task used in this research,[1] participants were asked to track a single unique target object moving among a set of distracter objects. The objects were moving along a random trajectory on a 3×3 grid. Participants were asked to report the last location visited by the target object before it disappeared. Each of the nine grid locations was identified by a popular cartoon character both to increase children's engagement and to assist in reporting the last location visited by the target. There were two experimental conditions: the Homogeneous Distracters condition and the Heterogeneous Distracters condition. In the Homogeneous Distracters condition, all distracters were identical to each other (e.g., red triangles) and different from the target object (e.g., a blue square) (see Fig. 1A for an example). In the Heterogeneous Distracters condition, all distracters were different from each other (e.g., a red triangle and a green diamond) and from the target (e.g., a blue square) (see Fig. 1B for an example).

It was expected that performance in the Heterogeneous Distracters condition should reflect the contribution of predominantly endogenous factors. Children performed the task to comply with the request of an adult and not because the task was sufficiently motivating to engage in it in the absence of such a request (as opposed to, e.g., free play with novel toys). Furthermore, the task provided no contextual support that could benefit performance (e.g., target objects were not more salient than distracters). In the Homogeneous Distracters condition, each target object was unique, and therefore more salient, than distracters. Thus, performance in this condition was expected to reflect the contributions of both endogenous factors (e.g., exhorting effortful control to comply with a request of an adult) and exogenous factors (e.g., higher saliency of target objects compared with distracters). Therefore, any improvement in performance in the Homogeneous Distracters condition should reflect the unique contribution of exogenous factors to performance on this task at different points in development.

Experiment 1

Method

Participants

The final sample in Experiment 1 consisted of 15 3-year-olds (M = 3.66 years, SD = 0.28, 8 girls and 10 boys), 18 4-year-olds (M = 4.49 years, SD = 0.25, 5 girls and 13 boys), and 18 5-year-olds (M = 5.23 years, SD = 0.23, 7 girls and 11 boys). An additional 10 3- and 4-year-olds participated in one testing session but were absent during the second testing session (see details below). Data from these children are not included in the analyses reported below. All participants in this and all other experiments reported in this article were recruited from several day care centers in a large mid-Atlantic city of the United States.

Stimuli

In the Track-It task, participants are presented with a 3×3 grid (each of the nine locations is marked by a unique cartoon character; see Fig. 1) and asked to track a single target object moving among distracters. When all of the objects disappear from the screen, participants are asked to indicate which of the nine grid cells the target was in when it disappeared. In this experiment, the target object was paired with two distracters. Target and distracter objects were randomly selected on each trial from a pool of nine unique objects (e.g., purple start, green diamond; see Fig. 2 for the complete set). The target and distracter objects subtended approximately 2.8° of the visual angle at a viewing distance of 50 cm. In the experiments presented below, the speed of motion for all target and

[1] The software running this task is made available for download to all researchers interested in using it at http://www.psy.cmu.edu/~trackit.

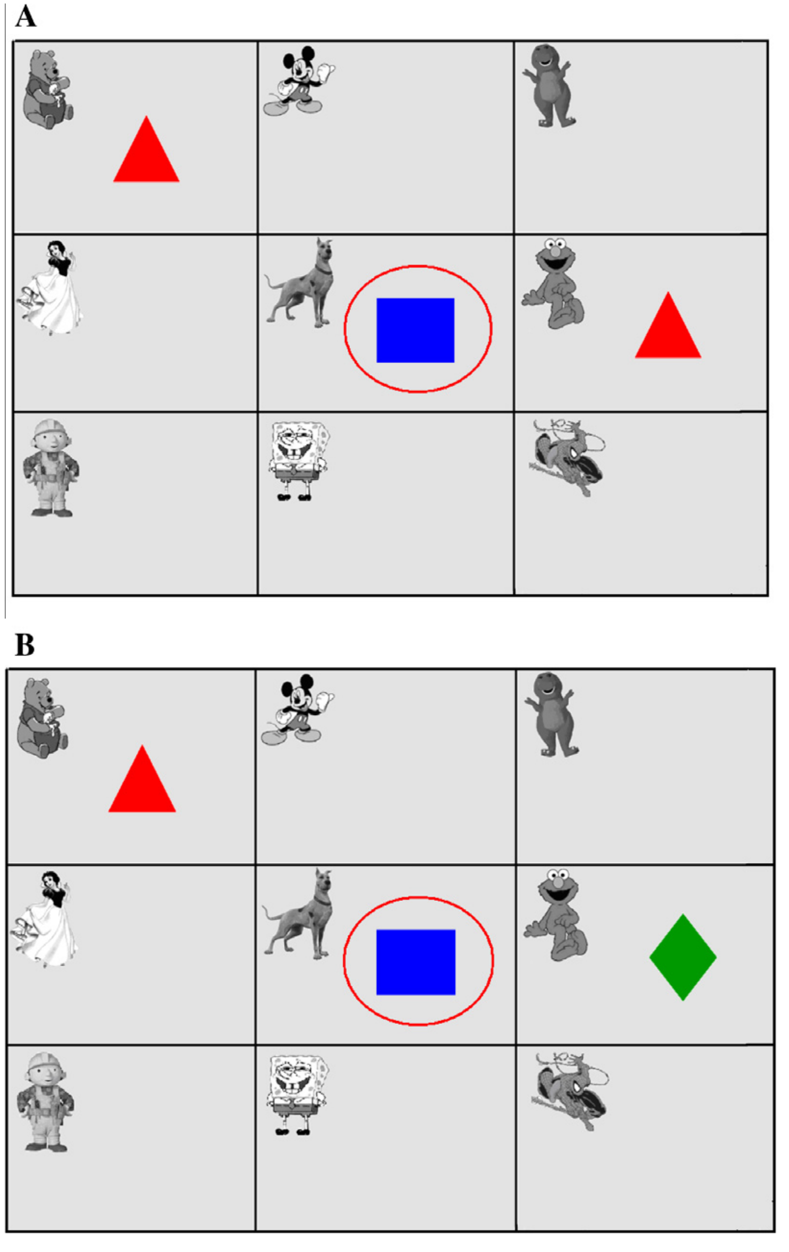

Fig. 1. Schematic depiction of the Track-It task in the Homogeneous Distracters condition (A) and Heterogeneous Distracters condition (B). At the beginning of each trial, the target object was clearly identified by being circled in red; the red circle disappeared as soon as the objects started moving. The starting position of the target objects was randomized on each trial.

distracter objects was set at 800 pixels per frame at 30 frames per second (this speed was chosen during pilot testing with a separate group of 3- to 5-year-olds).

At the beginning of each trial, participants viewed the objects in a static image, and the object designated as the target was clearly marked by a red circle surrounding it. The starting position of

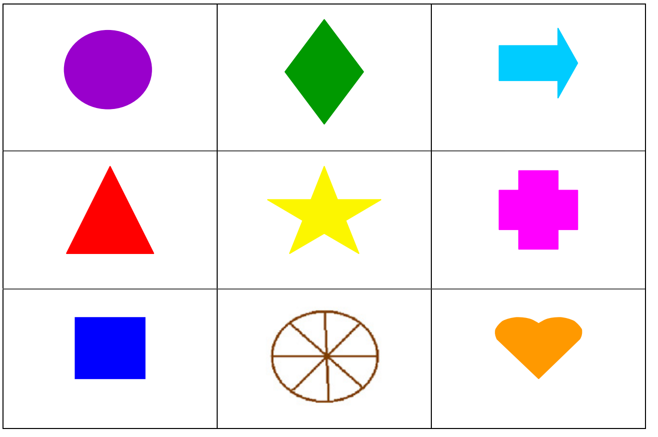

Fig. 2. Schematic rendition of the pool of nine unique objects that could be randomly chosen to serve as Targets and Distracters in Experiments 1-3. Actual colors for the top row shapes, left to right: purple, green, aqua; middle row left to right: red, yellow, pink; bottom row left to right: royal blue, brown, orange. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the target was randomized on each trial (i.e., the target could occupy any of the nine cells on the grid). All objects remained static until the experimenter ensured that participants were ready to begin each trial; trials were initiated by the experimenter via a button press. When a trial was initiated, the red circle disappeared and the objects began to move. There were no restrictions on the motion path of the distracters, but there were two restrictions on the motion path of the target object. First, the target needed to visit all nine cells before the objects disappeared. Second, the target needed to be in the middle of a cell when the objects disappeared in order to reduce possible confusion for participants in reporting its final location. Due to these restrictions, the duration of motion in each trial was not fixed but rather varied slightly from trial to trial. The minimum trial length was set to 10 s; actual trial lengths were on average 11.00 and 10.98 s in the Homogeneous Distracters and Heterogeneous Distracters conditions, respectively.

Design and procedure

Experiment 1 had a 3 (Age: 3-, 4-, or 5-year-olds) × 2 (Experimental Condition: Homogeneous Distracters or Heterogeneous Distracters) mixed design, with condition as a within-participant variable. The order of these conditions was counterbalanced across participants. Conditions were completed in two separate testing sessions. For most children, both testing sessions were administered within a 3-week period; however, for a small subset of children ($n = 5$), the sessions were administered up to 5 weeks apart (due to child illness or other unforeseen circumstances). The average length of delay between the testing sessions was 13 days ($SD = 10.42$). All participants were tested by a hypothesis-blind experimenter in a quiet room in their day care center.

At the beginning of the task, participants were told that (a) the objects would start moving over the grid once the experimenter presses a button, (b) at some point the objects would disappear behind the cartoon characters, and (c) the goal of the task was to watch the target object carefully while it moved and report (verbally or by pointing) the grid location where the target object disappeared. Participants were also asked to remember the identity of the target object on each trial for a subsequent test of memory accuracy (this memory check procedure is described in detail below). Participants completed 11 trials of the Track-It task in each condition. The first trial was completed with assistance from the experimenter, who traced the moving target object with their index finger. Participants were then told that they would need to complete the rest of the task (i.e., the remaining 10 trials) by themselves, tracking the target objects with their eyes only. Memory checks were administered after all 11 trials.

Table 1
Average memory accuracy by age group and condition in Experiments 1 and 2.

	Homogeneous distracters	Heterogeneous distracters
Experiment 1 (two distracters, minimum trial length = 10 s)		
3-year-olds	.69 (.22)	.65 (.22)
4-year-olds	.83 (.17)	.83 (.17)
5-year-olds	.86 (.13)	.86 (.22)
Experiment 2 (six distracters, minimum trial length = 10 s)		
3-year-olds	.47 (.31)	.44 (.39)
4-year-olds	.75 (.29)	.73 (.29)
5-year-olds	.81 (.19)	.86 (.20)

Note. Standard deviations are in parentheses.

Memory check

At the conclusion of each trial, participants were asked to identify which object served as the target. The memory checks were introduced to help discriminate between two possible reasons why a participant might fail to correctly report the location where the target object disappeared. The first possibility is that encoding of the identity of the target object may be insufficiently strong to persist through an entire trial; this would indicate an encoding failure. The second possibility is that a child may track distracters for a part of the trial despite remembering which object was supposed to be watched; this would indicate the failure of selective sustained attention. At the conclusion of each trial, children were presented with a laminated card depicting all nine shapes that could serve as target objects in this task (presented in Fig. 2) and were asked to point to the shape they had been tracking. The responses to memory check questions were manually recorded by the experimenter.

Results

Memory accuracy

Responses to individual memory check questions (i.e., "Which object were you supposed to watch?") were averaged over the 10 experimental trials to yield a *memory accurac*y score for each participant. There was no effect of order on memory accuracy scores in any of the age groups in either experimental condition, all independent-sample *p*s > .36; therefore, memory accuracy scores were collapsed across the orders of presentation. Memory accuracy data[2] are presented in Table 1 separated by age group and condition. In all conditions and age groups, memory accuracy was above chance (11% given nine response options), all one-sample *t*s > 9.71, *p*s < .0001. To investigate possible effects of age and condition, memory accuracy scores were submitted to a mixed-design analysis of variance (ANOVA) with age as a between-participant factor and experimental condition as a within-participant factor. This analysis indicated a main effect of age, $F(2,46) = 5.79$, $p < .005$, $\eta_p^2 = .201$. Post hoc Tukey's HSD tests indicated that overall memory accuracy was lower in 3-year-olds ($M = .67$) than in both older age groups ($p < .05$) and statistically equivalent in 4- and 5-year-olds (*M*s = .83 and .86, respectively). Most important, however, there was no effect of condition and no age by condition interaction (both *F*s < 1, *ns*). Therefore, any differences in object tracking accuracy between conditions are unlikely to stem from differences in the strength of encoding of the target objects.

Tracking accuracy

Responses to questions about the final position of the target object (i.e., "Where did the object disappear?") were averaged over the 10 experimental trials to yield a *tracking accuracy* score for each participant. The analyses in this section were conducted on all 10 experimental trials (i.e., tracking accuracy scores included trials on which children both succeeded and failed to correctly report the identity of the target object during the memory check). There was no effect of order on tracking

[2] Memory accuracy data were not available due to experimenter error for 1 4-year-old in the Heterogeneous Distracters condition and 1 5-year-old in the Homogeneous Distracters condition.

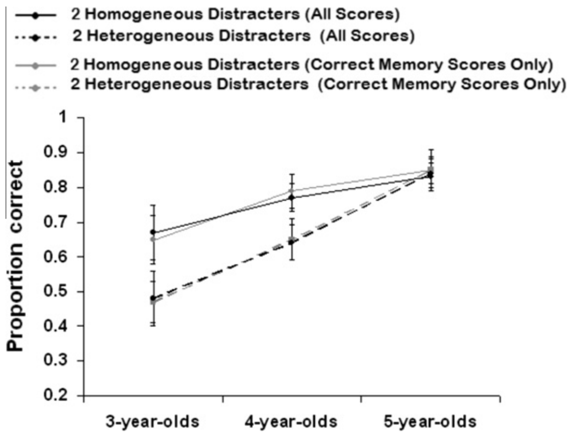

Fig. 3. Tracking accuracy scores in Experiment 1 separated by age group and experimental condition. Error bars indicate the standard errors of the means.

accuracy in any of the age groups in either experimental condition, all independent-sample *ps* > .11; thus, the scores were collapsed across orders of presentation. Tracking accuracy scores were submitted to a mixed-design ANOVA with experimental condition as a within-participant factor and age as a between-participant factor. This analysis revealed a main effect of experimental condition, $F(1,48) = 11.97$, $p < .002$, $\eta_p^2 = .20$, and a main effect of age $F(2,48) = 7.47$, $p < .005$, $\eta_p^2 = .237$. The main effects were qualified by an age by condition interaction, $F(2,48) = 3.35$, $p < .05$, $\eta_p^2 = .122$. As shown in Fig. 3, 5-year-olds were equally accurate in both experimental conditions, averaging 83% of correct responses in each condition. However, the effect of condition was significant for younger children, which gave rise to the interaction noted above. Younger children exhibited higher tracking accuracy in the Homogeneous Distracters condition than in the Heterogeneous Distracters condition: 76% versus 65% correct in 4-year-olds, paired-sample $t(17) = 2.39$, $p < .05$, Cohen's $d = 0.57$; 67% versus 48% correct in 3-year-olds, paired-sample $t(14) = 2.63$, $p < .05$, Cohen's $d = 0.77$.

Relationship between memory accuracy and tracking accuracy

To further investigate the possible relationship between memory accuracy and tracking accuracy, memory scores were correlated with tracking scores, separated by age group and experimental conditions. In the Homogeneous Distracters condition, memory accuracy scores were not significantly correlated with tracking accuracy scores for any of the three age groups (*rs* = .26, .14, and −.24 for 5-, 4-, and 3-year-olds, respectively, all *ps* > .30). In the Heterogeneous Distracters condition, memory accuracy scores were not significantly correlated with tracking accuracy in younger children (*rs* = −.11 and −.10 for 4- and 3-year-olds, respectively, both *ps* > .67); however, the correlation was significant in 5-year-olds ($r = .50$, $p = .034$).

Due to the latter finding, tracking data were reanalyzed taking into account only those trials on which children correctly identified the target object. The criterion for inclusion in the reanalysis for each child was presence of at least three trials with a correct memory score in each experimental condition. Data from all children satisfied this criterion, and more than 96% of participants exceeded this criterion (i.e., most children contributed more than three trials in each condition to the reanalysis). The reanalysis data are presented in Fig. 3 in gray. As can be seen from the figure, when tracking accuracy was calculated only for the correct memory trials, the means were nearly unchanged (and the results of the analyses of tracking accuracy remained unchanged).

Overall, the results of Experiment 1 suggest that the ability to accurately track an object amid heterogeneous distracters shows more protracted development than the ability to accurately track an object amid homogeneous distracters. This is consistent with the prediction that the additional endogenous factors required for success in the Heterogeneous Distracters condition (the necessity to maintain a goal-relevant representation rather than relying on task context to highlight the goal) increase the difficulty of the task. Children's higher tracking accuracy in the Homogeneous Distracters condition is due to the greater contribution of exogenous factors, specifically the salience of the (unique) target object. These results indicate that the Track-It task provides an opportunity to investigate the contribution of both endogenous and exogenous factors supporting sustained selective attention in the same task.

Notice that 5-year-olds exhibited no effect of condition on tracking accuracy. However, it is possible that condition differences in tracking accuracy may emerge in 5-year-olds if the task difficulty is increased. This possibility was investigated in Experiment 2, where children were asked to track target objects moving amid an increased number of distracter objects (i.e., six distracters).

Experiment 2

Method

Participants

The final sample in Experiment 2 consisted of 15 3-year-olds ($M = 3.33$ years, $SD = 0.27$, 6 girls and 9 boys), 18 4-year-olds ($M = 4.41$ years, $SD = 0.27$, 12 girls and 6 boys), and 18 5-year-olds ($M = 5.37$ years, $SD = 0.34$, 11 girls and 7 boys). An additional 14 children (6 3-year-olds, 4 4-year-olds, and 4 5-year-olds) participated in one of the two conditions but were absent during the second testing session, and 4 more children (1 3-year-old, 1 4-year-old, and 2 5-year-olds) participated in one of the two sessions but did not finish the task. Data from these children are not included in the analyses reported below.

Stimuli, design, and procedure

The materials and design of Experiment 2 were identical to those of Experiment 1 with one important difference: The number of distracter objects was increased to six in Experiment 2 (compared with two distracters in Experiment 1). Mean trial durations were 11.00 and 10.92 s in the Homogeneous Distracters and Heterogeneous Distracters conditions, respectively. The procedure was identical to that in Experiment 1.

Results

Memory accuracy

As in Experiment 1, memory accuracy was above chance (11%) in all conditions and in all age groups, all one-sample ts > 4.28, ps < .005 (see Table 1). Memory accuracy scores were submitted to a mixed ANOVA with age as a between-participant factor and experimental condition as a within-participant factor. As in Experiment 1, there was no effect of condition and no condition by age interaction (both Fs < 1, *ns*). Just as in Experiment 1, there was a main effect of age, $F(2,48) = 11.33$, $p < .0001$, $\eta_p^2 = .34$. Post hoc Tukey's HSD tests indicated that overall memory accuracy in 3-year-olds ($M = .45$) was lower than in both older age groups ($p < .05$) and statistically equivalent in 4- and 5-year-olds (Ms = .74 and .84, respectively).

Tracking accuracy

Tracking accuracy scores in Experiment 2 are presented in Fig. 4. These scores were submitted to a mixed ANOVA with experimental condition as a within-participant factor and age as a between-participant factor. Results of this analysis revealed a main effect of experimental condition, $F(1,48) = 22.42$, $p < .0001$, $\eta_p^2 = .32$, and a main effect of age, $F(2,48) = 7.87$, $p < .005$, $\eta_p^2 = .25$. Unlike Experiment 1, the age by condition interaction was not significant, $F(2,48) < 1$, *ns*.

Similar to Experiment 1, participants in all conditions in all three age groups identified the final location of the target object at an above-chance level (11%), all one-sample ts > 2.44, ps < .03. However, unlike Experiment 1, 5-year-olds exhibited an effect of condition, achieving higher accuracy in the Homogeneous Distracters condition ($M = .63$) than in the Heterogeneous Distracters condition

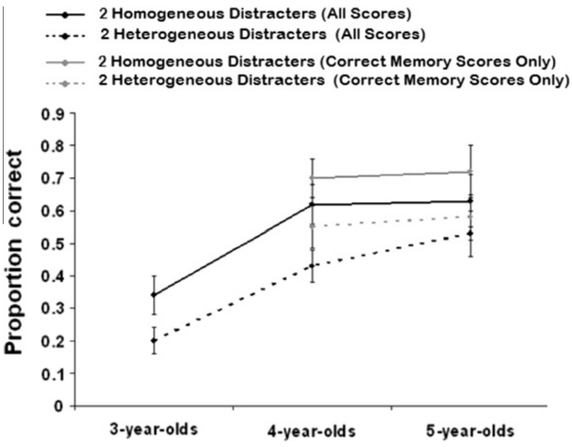

Fig. 4. Tracking accuracy scores in Experiment 2 separated by age group and experimental condition. Error bars indicate the standard errors of the means. Note that tracking accuracy scores corrected for memory accuracy (i.e., the correct memory scores only) are not shown on the graph for 3-year-olds because few participants in this age group provided usable data for this analysis (i.e., only 33% of 3-year-olds gave at least three correct responses to the memory check questions in each experimental condition).

($M = .53$), paired-sample $t(17) = 2.18$, $p < .05$, Cohen's $d = 0.31$. Similarly, 4-year-olds exhibited higher accuracy in the Homogeneous Distracters condition than in the Heterogeneous Distracters condition (Ms = .62 and .43, respectively), paired-sample $t(17) = 4.07$, $p < .005$, Cohen's $d = 0.82$, as did 3-year-olds (Ms = .34 and .21, respectively), paired-sample $t(14) = 2.07$, $p = .05$, Cohen's $d = 0.69$.

Across the two experiments, it appears that the overall level of performance in all three age groups was lower in Experiment 2, when six distracters were present, than in Experiment 1, when two distracters were present. Indeed, when the data from both experiments were submitted to a mixed ANOVA with age and number of distracters (two in Experiment 1 or six in Experiment 2) as between-participant factors and distracter type (homogeneous or heterogeneous) as a within-participant factor, the analysis revealed a main effect of number of distracters, $F(1,95) = 32.39$, $p < .0001$, $\eta_p^2 = .25$. There was also a main effect of distracter type, $F(1,95) = 33.02$, $p < .0001$, $\eta_p^2 = .26$, and a main effect of age, $F(2,95) = 14.99$, $p < .0001$, $\eta_p^2 = .24$. Post hoc Tukey's tests revealed that performance in the 3-year-old age group was significantly lower than in both older age groups (both ps < .005), whereas performance in 4-year-olds did not significantly differ from that in 5-year-olds ($p = .18$). There also was a marginally significant interaction between age and distracter type, $F(2,95) = 2.97$, $p = .056$, $\eta_p^2 = .06$, indicating that the difference in performance between different experimental conditions (Homogeneous Distracters or Heterogeneous Distracters) was more pronounced in younger children than in older children (the average difference in tracking accuracy between conditions collapsed across different number of distracters was 16% in 3- and 4-year-olds and only 5% in 5-year-olds). No other interactions were statistically significant (ps > .26).

Relationship between memory accuracy and tracking accuracy

In the Homogeneous Distracters condition, the correlation between memory accuracy and tracking accuracy scores did not reach significance for any of the three age groups (rs = .38, .20, and .40 for 3-, 4-, and 5-year-olds, respectively, all ps > .11). In the Heterogeneous Distracters condition, the correlation was significant in 3- and 5-year-olds (rs = .72 and .48, respectively, both ps < .05) and marginally significant in 4-year-olds ($r = .42$, $p = .08$).

Tracking accuracy data were reanalyzed taking into account only those trials on which children gave correct responses on memory questions. Similar to Experiment 1, the criterion for inclusion in the reanalysis for each child was the presence of at least three trials with a correct memory score in each experimental condition. Among 5-year-olds, 17 of 18 children (94%) satisfied this criterion, and among 4-year-olds, 15 of 18 children (83%) satisfied this criterion. However, among 3-year-olds, only 5 of 15 children (33%) satisfied this criterion, leaving too few 3-year-olds for the reanalysis. Therefore, reanalysis in Experiment 2 was conducted only on the scores of 4- and 5-year-olds. The reanalysis data are presented in Fig. 4 in gray.

Unlike Experiment 1, removing trials on which children failed to correctly identify the target object increased the tracking accuracy scores by 7 to 9%. However, there was a similar level of increase in tracking accuracy in both experimental conditions (Homogeneous Distracters and Heterogeneous Distracters), and the differences in tracking accuracy between experimental conditions remained significant for both 4- and 5-year-olds, both paired-sample ts > 2.68, ps < .05.

Overall, the findings of Experiment 2 suggest that increasing the number of distracters increased the difficulty of the Track-It task, with decrements in performance evident in all three age groups in both memory accuracy and tracking accuracy. Furthermore, when the number of distracters was increased from two to six, a relationship between memory encoding and selective sustained attention emerged, but only in the more challenging condition, the Heterogeneous Distracters condition, which is thought to place greater demands on endogenous factors (i.e., maintaining goal-relevant representations) than the Homogeneous Distracters condition.

Experiment 3

The results of Experiments 1 and 2 indicate that the Track-It task provides a unique opportunity to assess, in the same task, both the endogenous and exogenous factors supporting selective sustained attention in children. These experiments demonstrated that selective attention is easier to sustain when both exogenous and endogenous factors contribute to tracking the target (in the Homogeneous Distracters condition) than when children must rely primarily on endogenous factors (representing the goal in the Heterogeneous Distracters condition). In addition, Experiment 2 demonstrated that variations in the number of distracters influence task difficulty, meaning that the Track-It task is flexible enough to be used with a variety of age groups as different features of the paradigm are parametrically varied.

Experiment 3 extended these results in two directions. First, we assessed another parametric variation of the Track-It task—trial length. In Experiment 3, the minimum trial duration in the Track-It task was increased from 10 to 30 s; the number of distracters was two, the same as in Experiment 1. Second, Experiment 3 assessed the construct validity of the Track-It task. Given the paucity of experimental paradigms assessing selective sustained attention in preschoolers, we chose to assess convergent validity of the Track-It task using a measure of learning in a simulated classroom environment. If, as we hypothesized, the Track-It task taps into children's ability to sustain attention, children's performance in the Track-It task should be related to performance on other tasks that are systematically related to sustained selective attention. It has been suggested that sustained attention is crucially important for learning in naturalistic contexts such as classrooms (e.g., Bloom B. S., 1976; Carroll, 1963). Therefore, we expected children's tracking accuracy scores to be positively related to their learning scores. To evaluate divergent validity of the Track-It task, we investigated whether children's performance on this task was related to measures of children's general intelligence, as indexed by the Wechsler Preschool and Primary Scale of Intelligence (WPPSI).

Method

Participants

The final sample consisted of 22 kindergarten-age children (mean age = 5.30 years, SD = 0.33, 12 girls and 10 boys) from a University Lab School. Data from 1 additional participant were excluded from the analyses due to a developmental disability reported by school teachers. For the Classroom Learning task, children were assigned to one of two groups. Stratified random assignment was used to equate groups on age and gender (Group 1: n = 11, mean age = 5.30 years, SD = 0.29, 6 girls and 5 boys; Group 2: n = 12, mean age = 5.29 years, SD = 0.38, 6 girls and 6 boys).

Design and procedure

Classroom Learning task. Participants were brought into a laboratory classroom for 15 short lessons.[3] All lessons occurred over the course of a 3-week period (5 lessons per week). The mean lesson duration was 7.33 min. All lessons were conducted by the third author. After each mini-lesson, children were administered a paper-and-pencil assessment to evaluate their retention and comprehension of the lesson content. Additional measures were collected from the children during the Classroom Learning task; these measures are not included in the description and analysis of Experiment 3 and will be reported elsewhere.

Due to space constraints, all participants were divided into two groups; both groups received equivalent instruction, and all of the lessons were presented to both groups on the same day in the same order. During the lessons, children sat in a semicircle facing the teacher. Children's seating arrangement was randomly assigned at the beginning of the study.

Lessons. Each lesson consisted of a short read-aloud that served to introduce children to the lesson content. Lesson topics included matter, weather, bugs, flight, volcanoes, bones, water, fish, plate tectonics, gravity, rainbows, plants, solar system, stone tools, and bats (see Fig. 5A for an example). Lessons were classified as pertaining to one of four science domains: (a) life science, (b) earth science, (c) physical science, or (d) science technology. Lesson order was based on stratified random assignment that allowed for an approximately even distribution of the science domains across each week of the study.

Prior to the commencement of the study, none of the lesson topics had been formally taught to children by their kindergarten teachers. Although children may have had some exposure to the aforementioned topics outside of school, they had not received formal instruction on these topics during the current school year. However, during the course of the study, children completed a unit on bones. To control for lesson novelty, data from the bones lesson was removed from the analyses.

Assessments. At the end of each lesson, assessments were administered to measure student learning. Assessments consisted of a short paper-and-pencil workbook. All workbooks included 12 questions pertaining to the lesson of the day. For each question, participants were asked to select the correct answer from four pictorial response options. Across all lessons, there were 84 comprehension questions and 84 recognition questions. For the recognition questions, response options included one familiar picture (i.e., an illustration that children saw during the read-aloud) and three novel lures. Comprehension questions were designed in such a way that a sense of familiarity with the picture was not sufficient to respond correctly. Therefore, some of the comprehension questions consisted of all novel response options ($n = 72$) and some consisted of all familiar response options (i.e., an illustration that children saw during the read-aloud, $n = 12$). An example of lesson content and assessment question is presented in Fig. 5. All instructions on completing the assessments were given verbally by the third author. The assessment component of the study took approximately 10 min per lesson.

Track-It task. The Track-It task was administered after participants completed the Classroom Learning task; the average length of delay between the tasks was 2.47 weeks ($SD = 0.72$). The procedure for the Track-It task was identical to that in Experiment 1 with the exception of minimum trial duration, which was extended from 10 to 30 s. The mean trial durations were 37.86 s ($SD = 4.92$) in the Homogeneous Distracters condition and 37.36 s ($SD = 3.90$) in the Heterogeneous Distracters condition. All participants completed the task in both experimental conditions during two separate testing sessions with the order of conditions counterbalanced. All participants were tested by a hypothesis-blind experimenter in a quiet room adjacent to the children's classroom.

Intelligence test. Five months after the Classroom Learning task ($M = 5.66$ months, $SD = 0.41$), participants were administered the WPPSI. Eight WPPSI subscales were administered over four separate testing sessions (two subscales were administered per testing session). Testing sessions were typically completed over a 2-week period (approximately two testing sessions per week). This was done to

[3] Not all children were present for all 15 lessons due to illness or other unforeseen circumstances; on average, the attendance rate was 88% ($SD = 17$).

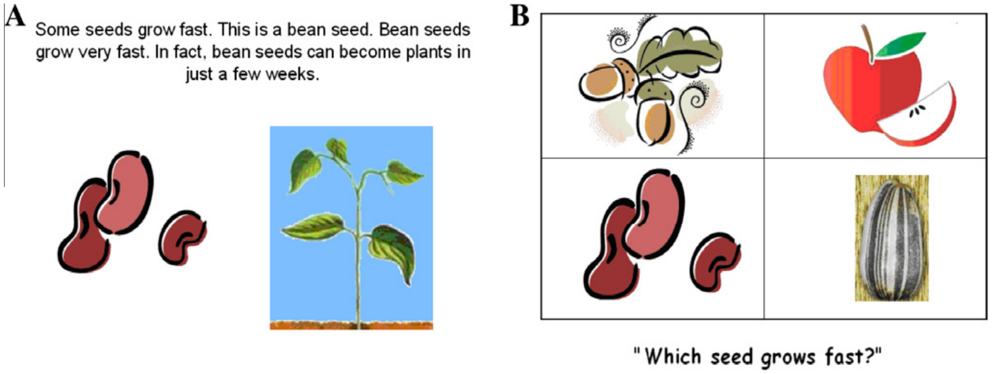

Fig. 5. (A) Sample content from the "plants" lesson. (B) Sample comprehension question from the "plants" lesson. In this example, all of the response options were illustrations that children saw during the read-aloud (i.e., all four response options were familiar). All instructions were given verbally by the teacher (i.e., the third author).

comply with the school's requirement to not have a child absent from the classroom for longer than 15 min.

Results

Memory accuracy

Pairwise *t* tests were conducted to determine whether memory accuracy differed as a function of experimental condition. Children were able to identify the target object with high levels of accuracy in both conditions: There were no significant differences between the Homogeneous Distracters and Heterogeneous Distracters conditions ($M = 0.77$, $SD = 0.22$, and $M = 0.82$, $SD = 0.23$, respectively), paired-sample $t(21) = 1.47$, $p = .16$.

Tracking accuracy

Pairwise *t* tests were conducted to determine whether object tracking accuracy differed as a function of experimental condition. Consistent with the results from this age group in Experiment 1, tracking accuracy was statistically equivalent in the Homogeneous Distracters condition ($M = 0.59$, $SD = 0.29$) and the Heterogeneous Distracters condition ($M = 0.55$, $SD = 0.32$), paired-sample $t(21) = 0.71$, *ns*.

Relationship between memory and tracking accuracy

Similar to Experiments 1 and 2, in the Homogeneous Distracters condition, the correlation between memory and tracking scores was not significant ($r = .25$, $p = .27$). The correlation between memory and tracking scores also did not reach significance in the Heterogeneous Distracters condition ($r = .40$, $p = .07$). Based on these findings and the overall high level of accuracy on memory questions in the Track-It task, we did not conduct a reanalysis of the tracking data in Experiment 3.

Effect of trial duration on tracking accuracy

To examine the effect of minimum trial duration (10 or 30 s) on tracking performance, we compared 5-year-olds' tracking accuracy in Experiment 1 with children's tracking accuracy in Experiment 3. As noted previously, in both experiments there were no significant differences in tracking accuracy as a function of experimental condition (Homogeneous Distracters or Heterogeneous Distracters). Consequently, for this analysis we averaged tracking accuracy scores across the experimental conditions. The results of this analysis revealed that 5-year-olds were markedly more accurate on the Track-It task in Experiment 1 ($M = .83$, $SD = .16$) than in Experiment 3 ($M = .57$, $SD = .28$).

This difference was statistically significant, independent samples $t(37) = 3.32$, $p = .005$, and the effect size was large, Cohen's $d = 1.14$.

It is not surprising that trial duration was found to be an important factor in how well young children are able to maintain selective attention. However, the increased minimum trial duration of 30 s was relatively short for a task of sustained attention. Therefore, the level of decrease in children's performance was quite remarkable.

Effect of trial duration on memory accuracy in Track-It task

To examine the effect of trial duration on memory accuracy, we compared memory accuracy scores for 5-year-olds in Experiments 1 and 3. As noted previously, in both experiments there were no significant differences in memory accuracy as a function of experimental condition. Consequently, for this analysis we averaged memory accuracy scores across the experimental conditions. The average memory accuracy scores of 5-year-olds in Experiment 1 ($M = .86$, $SD = .14$) were not statistically different from the average memory accuracy scores in Experiment 3 ($M = .80$, $SD = .21$), independent samples $t(38) < 1$, *ns*. Therefore, increased trial duration resulted in decreased performance on the selective sustained attention component of the task, but not on the memory encoding component of the task.

Classroom Learning task

Children's performance on the learning assessments was averaged across all lessons to obtain a comprehension score, a recognition score, and a total learning score (i.e., the average rate of correct responses on all questions). The mean comprehension scores ($M = .60$) were higher than the recognition scores ($M = .51$), paired-sample $t(21) = 2.25$, $p < .05$. The mean total learning score was 56%. All of the assessment scores were above chance (25%), all single-sample *t*s > 4.67, *p*s < .0001.

Next, we examined whether children's memory accuracy and tracking accuracy on the Track-It task were related to children's scores on the Classroom Learning task. For these analyses, the scores on the Track-It task were averaged across the Homogeneous Distracters and Heterogeneous Distracters conditions due to the absence of condition differences. The memory and tracking accuracy scores averaged across conditions in the Track-It task were not significantly correlated with each other ($r = .35$, $p = .11$).

Children's total learning score was significantly correlated with both memory accuracy ($r = .61$, $p = .002$) and tracking accuracy ($r = .53$, $p = .01$). Although children's recognition scores appeared to be more strongly correlated with memory accuracy ($r = .63$, $p = .002$) than with tracking accuracy ($r = .49$, $p = .02$), and children's comprehension appeared to be more strongly correlated with tracking accuracy ($r = .52$, $p = .014$) than with memory accuracy ($r = .45$, $p = .033$), the differences in the strength of these correlations were not statistically significant (both *p*s > .49).

IQ scores

Children's scores on the eight WPPSI subscales were combined to obtain four composite IQ scores: verbal IQ, performance IQ, processing speed, and full-scale IQ. All mean composite scores were in the

Table 2
Intercorrelations for IQ subscales and Track-It performance indexes (memory accuracy and tracking accuracy).

	Memory accuracy (Track-It)	Tracking accuracy (Track-It)
Performance IQ	.25	.19
Processing speed	.20	.09
Verbal IQ	.73*	.24
Full-scale IQ	.55**	.21

* $p < .0001$.
** $p = .01$.

average or above-average range (verbal IQ: $M = 119.24$, $SD = 14.04$; performance IQ: $M = 111.43$, $SD = 15.19$; processing speed: $M = 100.86$, $SD = 15.04$; full-scale IQ: $M = 114.57$, $SD = 12.98$).

Correlations among IQ scores, memory accuracy, and tracking accuracy are presented in Table 2. As can be seen from the table, tracking accuracy was not significantly related to any of the WPPSI subscales or to the full-scale IQ scores (all r values were in the range of 0.094–0.24, all $ps > .30$). Memory accuracy was not significantly related to performance IQ and processing speed (both $rs < .25$, $ps > .28$). However, memory accuracy scores were highly correlated with verbal IQ ($r = .73$, $p < .0001$), leading to a significant correlation between memory accuracy and full-scale IQ ($r = .55$, $p = .01$).

Predicting learning scores on the Classroom Learning task

The final analysis involved predicting children's learning scores on the Classroom Learning task from performance indexes of the Track-It task and the full-scale IQ scores.[4] For this analysis, tracking accuracy and memory accuracy scores were averaged across the experimental conditions (Homogeneous Distracters and Heterogeneous Distracters) due to a lack of significant differences between the conditions. All analyses described below were performed using backward stepwise regression with memory accuracy, tracking accuracy, and full-scale IQ as the three predictor variables. Due to a somewhat small sample size, variables were excluded from the regression model when p values were equal to or greater than .10.

The regression model significantly predicted children's recognition scores, $F(2, 19) = 8.81$, $p = .004$. Of the three predictors initially entered into the model, only two were retained: memory accuracy ($\beta = .52$, $p = .008$) and tracking accuracy ($\beta = .31$, $p = .097$). Full-scale IQ ($\beta = 0.23$, $p = .261$) was not found to be a significant predictor of the recognition scores. The adjusted R^2 value indicated that 43% of the variance in the recognition scores was explained by the two-predictor model.

The regression model also significantly predicted children's comprehension scores, $F(1, 20) = 7.31$, $p = .014$. Of the three predictors initially entered into the model, only one was retained: tracking accuracy ($\beta = .52$, $p = .014$). Memory accuracy ($\beta = .31$, $p = .130$) and full-scale IQ ($\beta = .26$, $p = .194$) were not found to be significant predictors of the comprehension scores. The adjusted R^2 value indicated that 23% of the variance in the comprehension scores was explained by the one-predictor model.

Finally, the regression model also significantly predicted children's total learning scores, $F(2, 19) = 9.09$, $p = .002$. Of the three predictors initially entered into the model, only two were retained: memory accuracy ($\beta = .49$, $p = .012$) and tracking accuracy ($\beta = .36$, $p = .053$). Full-scale IQ ($\beta = .21$, $p = .288$) was not found to be a significant predictor. The adjusted R^2 value indicated that 44% of the variance in the total learning scores was explained by the two-predictor model.

Discussion

Overall, the results of Experiment 3 yielded several novel findings. Compared with the results of Experiment 1, a small absolute increase in minimum trial duration from 10 to 30 s in the Track-It task resulted in a large decrease in tracking accuracy for kindergarten-age children. At the same time, increased trial length had no effect on children's memory accuracy. These findings suggest that the ability to sustain selective attention in young children is fragile and may be better measured on the order of seconds rather than minutes.

Furthermore, individual variability on both performance indexes of the Track-It task was predictive of children's learning scores in a mock classroom setting, whereas WPPSI full-scale IQ (as well as individual subscales) was not. We do not interpret this finding as an indicator that general intelligence abilities measured by IQ tests are not important for academic achievement. However, we believe that this finding indicates that one's ability to selectively sustain attention has a contribution to academic performance above and beyond general intelligence. Although this sentiment is not new, the results of Experiment 3 suggest that the Track-It task has promising convergent validity.

[4] The results of this analysis remain unchanged when IQ subscales are entered as predictors. However, given the relatively small sample size in this experiment ($N = 22$), we deemed it prudent to decrease the overall number of predictor variables.

Finally, similar to the CPT, the Track-It task also taps into multiple aspects of performance. However, the Track-It paradigm allows for separation of at least two factors affecting overall performance: the memory encoding component and the selective sustained attention component. The memory component was found to be related to some aspects of general intelligence as measured by the WPPSI, namely verbal IQ. At the same time, the selective sustained attention component was not related to any of the general intelligence abilities measured by the WPPSI. In other words, results of Experiment 3 suggest that the Track-It task also has promising divergent validity.

General discussion

From infancy through adulthood, the ability to sustain attention plays a critical role in learning and adaptive behavior (e.g., Kannass & Oakes, 2008; Thiessen, Hill, & Saffran, 2005; Toro, Sinnett, & Soto-Faraco, 2005). However, much of our understanding of the role of attention in learning and development comes from work with infants and adults. Preschool-age children present researchers with a measurement gap—too old to participate in preferential looking measures of attention commonly used with infants, but too young to participate in the more demanding tasks (e.g., the CPT) typically used with older children and adults. Our goal in the series of experiments reported in this article was to develop a paradigm for assessment of selective sustained attention in preschool-aged children. The results of these experiments suggest that the Track-It task is well-suited to these goals. The task is developmentally appropriate for preschool-age children; it results in neither ceiling nor floor effects, and the vast majority of participants are able to complete the task, unlike other assessments of selective attention that have been used in this age range. At the same time, it is likely that the Track-It paradigm may be successfully used with children older than 5 years because performance of 5-year-olds was far from ceiling, particularly in Experiments 2 and 3.

Just as important, the Track-It task allows for the investigation of endogenous and exogenous factors that support selective sustained attention *in the same task*. Experiments 1 and 2 indicate that performance on the selective sustained attention component of the Track-It task in younger children (3- and 4-year-olds) is influenced by exogenous factors to a greater degree than the performance in 5-year-olds. Specifically, younger—but not older—children exhibited higher tracking accuracy in the Homogeneous Distracters condition (in which the target objects were more salient than distracters) compared with the Heterogeneous Distracters condition (in which the target and distracter objects were equally salient). These findings support the general notion that development of executive control of selective sustained attention follows a protracted developmental course (e.g., Colombo & Cheatham, 2006; Ruff & Rothbart, 2001). Because the Track-It paradigm enables us to assess the contribution of exogenous and endogenous factors to selective sustained attention within the same task, it is possible to attribute changes in performance to the relative contributions of these factors rather than to task-specific factors, a problem that complicated interpretation of prior research on the development of mechanisms of selective sustained attention (Ruff & Rothbart, 2001).

In addition to these useful practical and theoretical features, the reported findings suggest that the Track-It task has strong construct validity. First, as indicated by Experiment 3, Track-It has good predictive validity. The ability to successfully select and sustain attention on a target object, as measured by children's ability to correctly identify the final grid that the target visited, predicted successful learning in a series of mock classroom lessons that occurred several weeks earlier. This is consistent with prior suggestions that sustained attention is crucially important for learning in naturalistic contexts such as classrooms (e.g., Bloom, 1976; Carroll, 1963). Furthermore, it suggests that the Track-It task is tapping into an individual difference in children that is at least somewhat stable, consistent with theoretical accounts of attention describing it as a consistent individual difference (e.g., Kane & Engle, 2002; Posner & Rothbart, 2007).

Second, the Track-It task has good discriminant validity. Two aspects of the data indicate that performance in the Track-It task can be uniquely ascribed to the ability to sustain selective attention rather than to other more general cognitive abilities. First, the results of Experiments 1 to 3 establish that differences in children's ability to successfully identify the target location cannot be attributed to differences in memory encoding. For example, tracking performance is better in the Homogeneous

Distracters condition than in the Heterogeneous Distracters condition even when the analyses include only those trials on which children succeeded in the memory task. This indicates that the Track-It task separates, and is capable of independently assessing, selective attention and memory encoding. The second indicator of the Track-It task's discriminant validity is that the regression analysis in Experiment 3 demonstrated that the Track-It task provides a predictor of performance in the Classroom Learning task that is not captured by variance in full-scale IQ or any of its subscales.

Finally, the results of Experiment 1 suggest that the Track-It task has good convergent validity. These results are consistent with prior theories and experiments suggesting that the contribution of endogenous factors increases over the course of development (Colombo & Cheatham, 2006; Ruff & Rothbart, 2001). Unlike 3- and 4-year-olds, 5-year-olds performed equivalently well in the Homogeneous Distracters and Heterogeneous Distracters conditions. This suggests that for 5-year-olds, the contributions of endogenous factors (primarily the maintenance of goal-related representations) are powerful enough that the increased contribution of exogenous factors (target salience) in the Homogeneous Distracters condition provided no additional performance boost when the task involved two distracters. This should not be taken to mean that 5-year-olds are completely adult-like in their ability to maintain goal-related representations. The results of Experiment 2 indicate that it is possible to observe an advantage for the Homogeneous Distracters condition at 5 years of age by increasing the number of distracters. We expect that other parametric manipulations of task difficulty (e.g., increasing the number of grid locations or the speed of object motion) may render the task useful for investigating sustained selective attention in children older than 5 years. Indeed, one of the attractive features of the Track-It paradigm is that the ability to parametrically vary task difficulty should make it possible to better quantify the relative contribution of endogenous and exogenous factors supporting sustained selective attention at different ages and task difficulties.

In addition to providing converging evidence for previous theoretical accounts, the Track-It task also opens avenues for novel investigations. Even in the experiments reported here, which have a primarily methodological focus, the Track-It task has provided novel information about the time course of sustained attention. In Experiment 3, a modest increase in trial duration, with average trial duration still being well under 1 min (i.e., 37 s), led to a substantial decrease in tracking accuracy in 5-year-olds. Notably, the trial duration increase had no appreciable effect on the memory component of the Track-It task. These findings are surprising in light of the play-based approaches and CPT tasks, which measure selective sustained attention in minutes. However, these findings are consistent with a recent report that selective sustained attention is better characterized as "periodic sampling" even in adult participants (Busch & VanRullen, 2010).

Unresolved issues

Future research with the Track-It task will help to further specify the developmental changes in selective sustained attention and the mechanisms underlying those changes. Consider, for example, the finding that tracking accuracy is higher for objects in the Homogeneous Distracters condition than in the Heterogeneous Distracters condition, a result that we have attributed to the additional contribution of exogenous factors (i.e., salience) in the former condition. Note, however, that there are two possible routes via which salience could potentially improve tracking accuracy. One possibility, consistent with the notion that the speed of engaging attention (or attention-getting) and the speed of releasing attention (or attention-holding) are separate factors (Cohen, 1972), is that homogeneous distracters provide less competition for attentional resources and, therefore, children are less likely to glance away from the target objects moving amid identical distracters. In other words, low competition for attentional resources may enhance attention-holding properties of the target. An alternative possibility is that children are equally likely to glance away from the target object regardless of the type of distracters; however, children are more successful in locating the target after glancing away in the Homogeneous Distracters condition than in the Heterogeneous Distracters condition. In other words, identical distracters may enhance attention-getting properties of the target. Both of these possibilities would be consistent with the results reported in these experiments, which reported solely the results of tracking accuracy at the *end* of the trial. However, as we have reported elsewhere (Thiessen, Dickerson, Erickson, & Fisher, 2012), it is possible to modify the Track-It task for use with an eye-tracker. This will provide the opportunity to analyze moment-by-moment data about the location of a child's gaze, making it possible to determine how often (and where) the child glances away from the target.

A related issue requiring further research is the interplay between target saliency and perceptual load of a visual display. In this article, we framed our predictions and findings in terms of higher saliency of the target object in the Homogeneous Distracters condition than in the Heterogeneous Distracters condition. However, it is possible to characterize the difference between these two conditions not only in terms of lower target saliency in the Heterogeneous Distracters condition than in the Homogeneous Distracters condition but also in terms of increased perceptual load in the former condition. Perceptual load is said to be increased if "either the number of items that need to be perceived is increased, or ... for the same number of items, perceptual identification is more demanding" (Lavie, 2006, p. 92). The perceptual load theory predicts better performance under the conditions of *higher perceptual load* because higher load is hypothesized to "engage full capacity in relevant processing," whereas under the conditions of low perceptual load "any capacity not taken up in perception of task-relevant stimuli would involuntarily 'spill over' to the perception of task-irrelevant distractors" (Lavie, 2005, p. 75).

In the experiments reported in this article, we observed superior performance under the conditions of *low perceptual load,* a finding that seemingly goes against the predictions of the perceptual load theory. However, it is worth noting at least two important differences between the extant studies on perceptual load and the current experiments. First, studies testing the effects of perceptual load on selective attention are typically conducted with adults, and to the best of our knowledge the youngest participants in the perceptual load studies were 7 years of age, which is quite a bit older than participants in the currently reported studies (Couperus, 2011). Perhaps more important, the perceptual load theory makes predictions about—and is tested in the domain of—selective attention but not sustained attention. Therefore, it is possible that effects of perceptual load manifest themselves differently when participants not only need to select an object for processing but also need to sustain attention to the selected object over time. Further research is required to examine this possibility as well as the possibility that the differences in tracking accuracy observed in the reported experiments stemmed—fully or partially—from the effects of increased perceptual load.

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