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After publishing this article online, the authors discovered a minor error in their A' calculations that resulted in barely noticeable errors in the reported values for this statistic. Additionally, in the raw data file, 2 (out of 1,120) trials were mislabeled, and 1 participant's subject number did not match between different phases of the experiment (the authors thank John Christie, of Dalhousie University, for helping them discover these errors). The authors have corrected these errors and added the corrected data file (without replacing the original data file) to their project at Harvard Dataverse (http://dx.doi.org/10.7910/DVN/7TA47E). The authors also have posted at Harvard Dataverse a table comparing the published and corrected A' statistics, analyses of variance, t tests, and effect sizes. Although some statistical terms, p values, and effect sizes changed, these changes were exceedingly small, and none of the reported effects became weaker as a result of these changes. The authors' decision to publish these corrections was driven by the desire to avoid confusion if the data are reanalyzed.

Research Article

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Costs of Selective Attention: When Children Notice What Adults Miss

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Abstract

One of the lawlike regularities of psychological science is that of developmental progression—an increase in sensorimotor, cognitive, and social functioning from childhood to adulthood. Here, we report a rare violation of this law, a developmental reversal in attention. In Experiment 1, 4- to 5-year-olds (n = 34) and adults (n = 35) performed a change-detection task that included externally cued and uncued shapes. Whereas the adults outperformed the children on the cued shapes, the children outperformed the adults on the uncued shapes. In Experiment 2, the same participants completed a visual search task, and their memory for search-relevant and search-irrelevant information was tested. The young children outperformed the adults with respect to search-irrelevant features. This demonstration of a paradoxical property of early attention deepens current understanding of the development of attention. It also has implications for understanding early learning and cognitive development more broadly.

Keywords

attention, cognitive development, learning, open data, open materials

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One of the lawlike regularities of psychological science is that of developmental progression—an increase in sensorimotor, cognitive, and social functioning from childhood to adulthood. It is hardly a coincidence that a similar developmental progression manifests itself in biology: Maturation results in increasingly complex and differentiated biological structures, capable of supporting increasingly complex functions.

Although the law of developmental progression may not hold for learning (e.g., acquiring a second language, learning to ride a bike, or learning to play a musical instrument is easier and more efficient in childhood than later on), it holds for the vast majority of cognitive and social processes. For example, developmental progression is found in attention (Plude, Enns, & Brodeur, 1994), memory (Cowan & Hulme, 1998), executive function (Zelazo et al., 2003), categorization (Deng & Sloutsky, 2016; Kloos & Sloutsky, 2008; Rabi & Minda, 2014; Sloutsky, 2010), inductive inference (López, Gelman, Gutheil, & Smith, 1992; Sloutsky, Deng, Fisher, & Kloos, 2015; Sloutsky, Kloos, & Fisher, 2007) logical thinking (Markovits & Barrouillet, 2002), metacognitive control (Dunlosky & Metcalfe, 2009), and moral reasoning (Smetana, 2006). One does not need to be a trained psychologist to firmly believe in developmental progression; parents hold such beliefs from observing their own children (Miller, 1988). Here, we report a rare violation of the law of progression—a developmental reversal in attention—and discuss its implications for understanding the development of selective attention and broader aspects of early learning and cognitive development.

Selective attention refers to a top-down process that subserves focusing on goal-relevant aspects of a task (Pashler, Johnston, & Ruthruff, 2001). Selective attention undergoes protracted development (for reviews, see Hanania & Smith, 2010; Plude et al., 1994). Infants and young children exhibit difficulty in focusing attention on a single dimension and filtering out extraneous information. By late childhood, however, individuals demonstrate marked improvements in both focusing and filtering. These developmental changes are observed in a variety

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of tasks, including those involving visual selection and visual search (Plude et al., 1994), rule use (Hanania & Smith, 2010), classification (Smith & Kemler, 1977), and category learning (Best, Yim, & Sloutsky, 2013; Deng & Sloutsky, 2016).

For example, in the flanker task, participants respond to a target (e.g., determine the direction of an arrow) that is flanked by distractors. On some trials, the flankers are congruent (i.e., they point to the same direction as the arrow), whereas on other trials, the flankers are either incongruent (i.e., they point to the opposite direction) or absent. Any interference from the flankers is evident as a facilitation effect in the congruent condition and as an interference effect in the incongruent condition. Efficient filtering should minimize interference effects, and there are substantial developmental improvements in filtering between the ages of 4 and 7 (Rueda, Posner, & Rothbart, 2005).

Smith and Kemler (1977) observed similar developmental changes using a different task. Children (5-, 8-, and 11-year-olds) were presented with triads of two-dimensional stimuli. In each triad, one stimulus was the target, and two others were test stimuli. One test stimulus matched the target on a single dimension (e.g., color) but had a different value on the second dimension (e.g., shape). The other test stimulus was similar to the target on both dimensions but did not match it exactly on either dimension. When asked to select the test item that matched the target, the 5-year-olds opted for the item with overall similarity to the target, whereas the older children preferred the item that matched the target on a single dimension.

More recently, Deng and Sloutsky (2016) presented 4-year-olds, 6-year-olds, and adults with a category-learning task. The categories had a rule-plus-similarity structure, such that each category had a single deterministic (or rule) feature and multiple probabilistic features. Therefore, participants could learn either a rule-based category (i.e., only the rule feature mattered) or a similarity-based category (i.e., all features mattered). When attention was directed to the rule, participants in all three age groups learned a rule-based category. However, whereas the adults and older children predominantly remembered categorization-relevant rule features, the younger children remembered all the features equally well.

These (and similar) findings suggest that young children (as well as infants) tend to distribute attention across multiple aspects of stimuli, including aspects that are not relevant to the goal. The development of attention between 4 and 7 years of age results in greater selectivity—the ability to focus on a few dimensions and filter out irrelevant information. Although selective attention has many benefits, including faster, more efficient processing of selected information, it also has some critical costs, the most important being that information that is not selected may not be fully processed (Coch, Sanders, & Neville, 2005). In contrast, distributed attention has neither the benefits nor the costs of selectivity. These observations suggest an important developmental reversal: If young children's attention is distributed, then they may exhibit better processing of task-irrelevant information than adults do. On the other hand, adults should (not surprisingly) have an advantage in processing task-relevant information.

The goal of the research presented here was to test this prediction. In what follows, we report two experiments in which we examined young children's and adults' processing of task-relevant and task-irrelevant information in a change-detection task (Experiment 1) and a visual search task (Experiment 2).

Experiment 1: Change Detection

On each trial of the change-detection task, participants were shown a target item consisting of overlaid outline shapes, one red and the other green, and then the test item, which also consisted of overlaid red and green shape (see Fig. 1a). Participants were asked (a) whether the first red shape was familiar or novel and (b) whether the second pair of shapes (i.e., the test item) was the same as the target item. The task began with a cuing phase, in which the red shape changed from the target to the test item on each trial, whereas the green shape remained the same. Thus, attention to the red shapes was cued, and the red shapes were considered task relevant. Because attention was directed away from the green shapes, they were uncued and considered task irrelevant. The main goal of the cuing phase was to attract participants' attention to the cued stream by giving them experience with changes in cued items only.

The same trial sequence used in the cuing phase was used in the subsequent testing phase. The crucial difference was the introduction of test items that gauged difference in attention to the relevant and irrelevant streams of information. On some test trials, the test item was exactly the same as the target item (i.e., both the cued and the uncued shapes were the same), whereas on other trials, either the cued shape or the uncued shape was changed. We predicted that young children would distribute their attention and consequently detect changes in both cued and uncued shapes, whereas adults, because of their greater attentional selectivity, would detect changes primarily in the cued shapes. As a result, we predicted that children would outperform adults in detecting changes in uncued shapes.

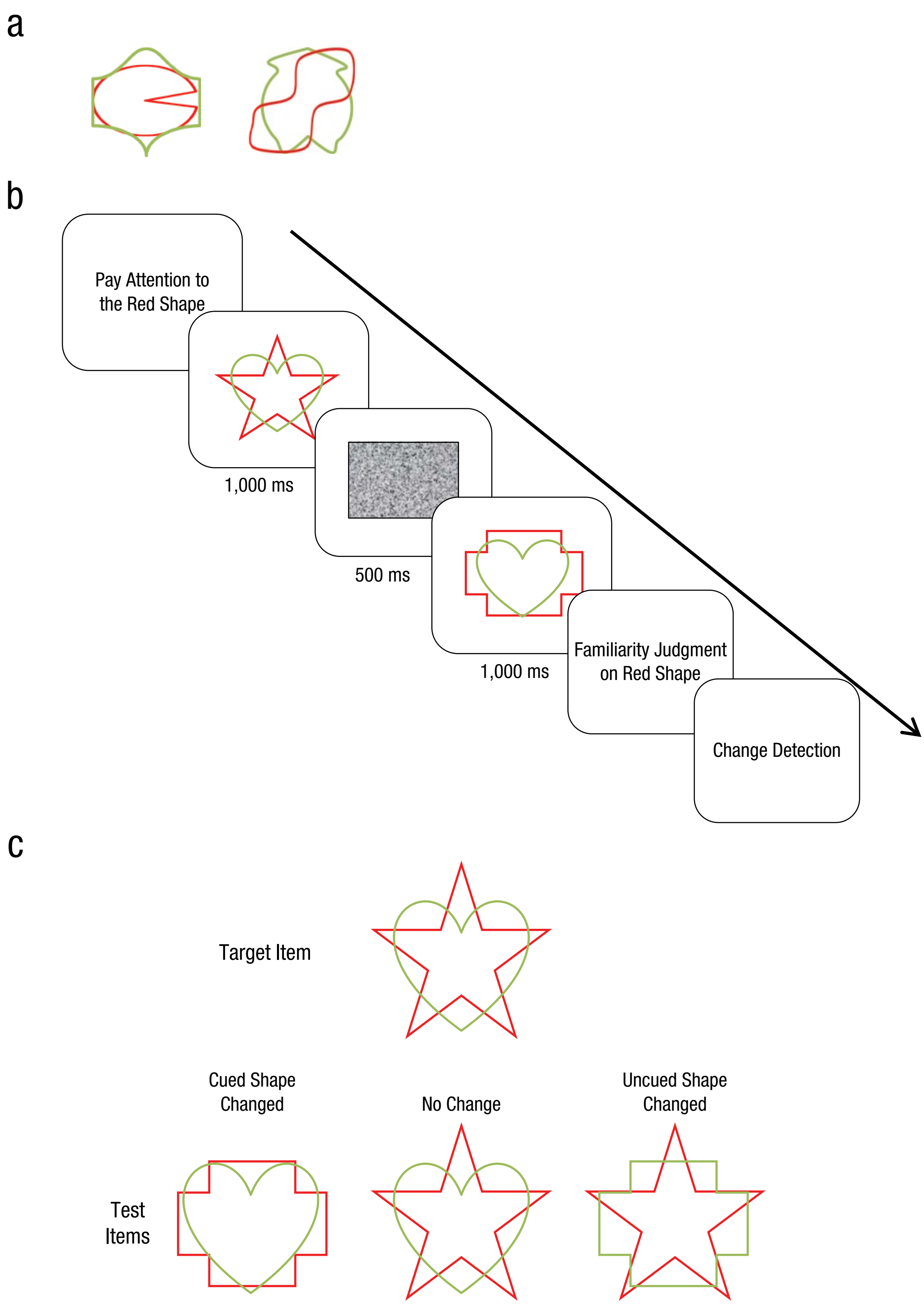

Fig. 1. Illustration of the change-detection task in Experiment 1: (a) examples of the stimuli, (b) illustration of the task sequence (with the red item being cued), and (c) examples of the stimuli presented in the three types of test trials.

Method

Participants. The sample consisted of 35 adults (mean age = 19.59 years, *SD* = 1.33 years; 18 women) and 34 children ages 4 to 5 years (mean age = 57.1 months, *SD* = 7.21 months, range = 48.5–68.0 months; 19 girls). Data from 4 adults (mean age = 19.8 years; 2 women) and 7 children (mean age = 60.2 months; 3 girls) were excluded because of poor test performance (i.e., more false alarms on old, unchanged, items than hits on cued-shape-changed and uncued-shape-changed items). Although there was no previous research on developmental reversals in attention, a previous study on developmental reversals in memory (Sloutsky & Fisher, 2004) included 27 to 30 participants per age group and had power greater than .8. Assuming a similar or smaller effect size in the current research, we recruited 34 to 35 participants per age group in order to achieve the same level of power.

The adults were undergraduate students at The Ohio State University; they participated in the experiment for course credit. The children were typically developing and had no reported vision, hearing, or developmental issues. They were recruited from the greater Columbus, Ohio, area and were tested either in the lab or in a quiet room in their childcare center.

Materials and design. The materials were 52 outline shapes, half of which were red and half of which were green (see Fig. 1). These shapes were combined into red-green pairs, with one shape overlying the other. Participants were asked to make judgments about the red (i.e., cued) shapes, but not the green (i.e., uncued) shapes. The experiment had a 2 (age group: children vs. adults) × 2 (shape type: cued vs. uncued) mixed design, with shape type as a within-subjects variable.

Procedure. For all participants, the experiment started with a warm-up phase designed to teach the children to pay attention to the screen and to respond to the questions. On each of 10 warm-up trials, participants saw a picture of a cat that had a semitransparent image of flowers laid on top of it and were told to pay close attention to the cat because they would be asked about it later. The picture was then shown again for 1 s, followed by a 500-ms mask and then the test item, which either was the same as the first picture or showed a frog instead of a cat. Participants were asked whether the cat had changed and received feedback as to whether their response was correct. Following the warm-up phase, participants proceeded to the experiment proper, which included cuing and testing phases.

The cuing phase (Fig. 1b) included five trials and was designed to focus participants' attention on shapes of a particular color (i.e., the red shapes). On each cuing trial, participants were asked to pay attention to the red shape, and then a target shape pair was presented for 1,000 ms. It was followed by a 500-ms mask and then a test shape pair, which was presented for 1,000 ms. Participants were asked if the red shape in the second (i.e., test) pair looked familiar. This familiarity judgment was followed by a change-detection judgment ("Did the picture change?"). To induce attention to the red shapes, we changed the red shape from the target to the test item on every cuing trial, whereas the green shape did not change between the target and test items. No feedback was given on cuing trials.

The testing phase contained 15 trials presented in a randomized order. The test trials were similar to the cuing trials with one critical difference concerning the relation between the two shape pairs presented on a given trial. We probed the allocation of attention to the cued and uncued shapes by including three trial types (see Fig. 1c): On *cued-shape-changed* trials, the cued shape was replaced by a different shape; on *uncued-shape-changed* trials, the uncued shape was replaced by a different shape; and on *no-change* trials, neither shape changed. The experiment was presented on a Dell laptop and was controlled by the Psychophysics Toolbox (Brainard, 1997). The adults recorded their responses on a keyboard, whereas the children made verbal responses that were recorded by the experimenter.

Results

Our analyses focused on change detection during the testing phase (see Table 1 for the proportions of "changed" responses). We measured change-detection accuracy using A', a nonparametric analogue of the signal detection statistic d' (Snodgrass & Corwin, 1988). We calculated A' separately for cued and uncued shapes for each age group (see Fig. 2). A' for cued shapes was calculated by defining hits as "changed" responses on cued-shape-changed trials and false alarms as "changed" responses on no-change trials. A' for uncued shapes was calculated by defining hits as "changed" responses on uncued-shape-changed trials and false alarms as "changed" responses on no-change trials.

Table 1. Proportion of "Changed" Responses for Each Trial Type in Experiment 1

	Trial type		
Age group	Cued shape changed (hits)	Uncued shape changed (hits)	No change (false alarms)
Adults	.92	.33	.14
Children	.83	.67	.26

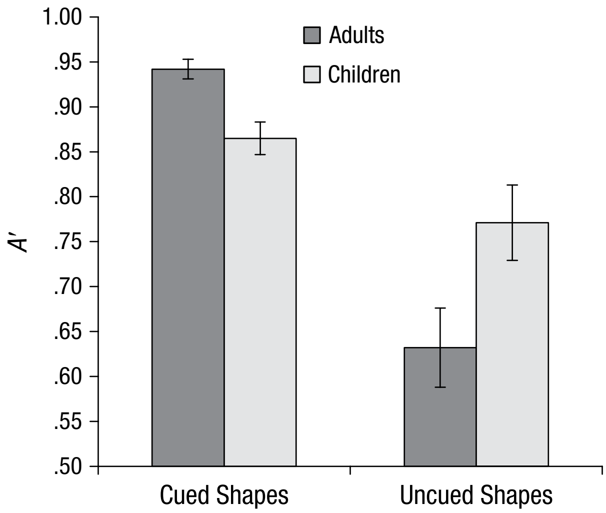

Fig. 2. Change-detection accuracy (*A′*) by shape type and age group in Experiment 1. Error bars represent ±1 *SEM*.

A 2 (shape type: cued vs. uncued) × 2 (age group: adults vs. children) mixed analysis of variance (ANOVA) was performed on the *A′* data. There was a significant interaction, $F(1, 56) = 13.04$, $p < .001$, $\eta^2 = .200$. Specifically, the adults outperformed the children in change detection for relevant information (.943 vs. .865), $t(56) = 3.79$, $p < .001$, $d = 1.00$, 95% confidence interval (CI) = [0.44, 1.54], whereas they lagged behind the children in detecting changes in irrelevant information (.634 vs. .771), $t(56) = -2.22$, $p = .030$, $d = -0.59$, 95% CI = [−1.11, −0.05]. Net accuracy (i.e., *A′* averaged across the cued and uncued shapes) did not differ significantly between the adults and children (.787 vs. .818, respectively, $p > .250$), although the children exhibited numerically greater net accuracy.

These results reveal important consequences of the development of selective attention, and they confirm the hypothesis that young children (who attend diffusely) exhibit better change detection for uncued shapes than do adults (who attend selectively). Specifically, the adults exhibited both benefits and costs of selectivity, processing task-relevant information more efficiently than the children but missing task-irrelevant information. In contrast, attending diffusely allowed the children to process information regardless of its relevance. To examine the generality of these findings, we conducted Experiment 2, in which the hypothesized developmental reversal in attention was tested using a visual search task.

Experiment 2: Visual Search

Experiment 2 used a visual search task in which stimuli had a task-relevant dimension and task-irrelevant dimensions. The relevant dimension was the one over which participants performed their search, whereas the irrelevant dimensions were the ones that could be ignored during search. Participants were tested on their ability to detect changes in the relevant and irrelevant dimensions. Because children attend diffusely, we expected that they would process both relevant and irrelevant dimensions, whereas because adults attend selectively, we expected that they would process primarily the relevant dimension. Therefore, we expected to observe a developmental reversal, with children exhibiting better processing of irrelevant dimensions than adults.

Method

Participants, materials, and design. The participants from Experiment 1 completed this experiment as well. The stimuli for the visual search task were arrays that contained six drawings of artificial creatures (Fig. 3a). There were four sets of creatures; each set had seven different binary feature dimensions. Participants were instructed to search for a target value on one of the dimensions, which was considered, the *relevant* dimension; all other dimensions were considered *irrelevant*. The target value was unique, as it was included in only one object in the search array.

The stimuli for the recognition phase were of three types (see Fig. 3b). The *old* items were stimuli that had been presented in the search arrays (targets or nontargets). *New relevant* items were created by taking an old item and replacing the feature on the relevant dimension with a completely new feature on that dimension. *New irrelevant* items were created by taking an old item and replacing a feature on an irrelevant dimension with a new feature on that dimension. The experiment had a 2 (age group: children vs. adults) × 2 (feature type: relevant vs. irrelevant) mixed design, with feature type as a within-subjects variable.

Procedure. The experiment consisted of a warm-up phase, a visual search phase, and a recognition phase. The goal of the warm-up was to teach participants the rules of the visual search task. Participants were first shown a smiley face and told that only one person in the upcoming search array would be smiling, and everyone else in the array would be frowning. They were then shown an array with six stick figures and asked to find the smiling person as fast as possible. The array remained displayed until participants selected an item. There were four trials in the warm-up phase, and participants received feedback as to whether their responses were correct.

The visual search phase consisted of eight trials using novel stimuli. Each search set was used on two trials, and the order of the search sets was randomized across participants. Each trial started by presenting the trial-specific target feature in the center of the screen, to attract attention to that feature (Fig. 3a). Participants were then shown

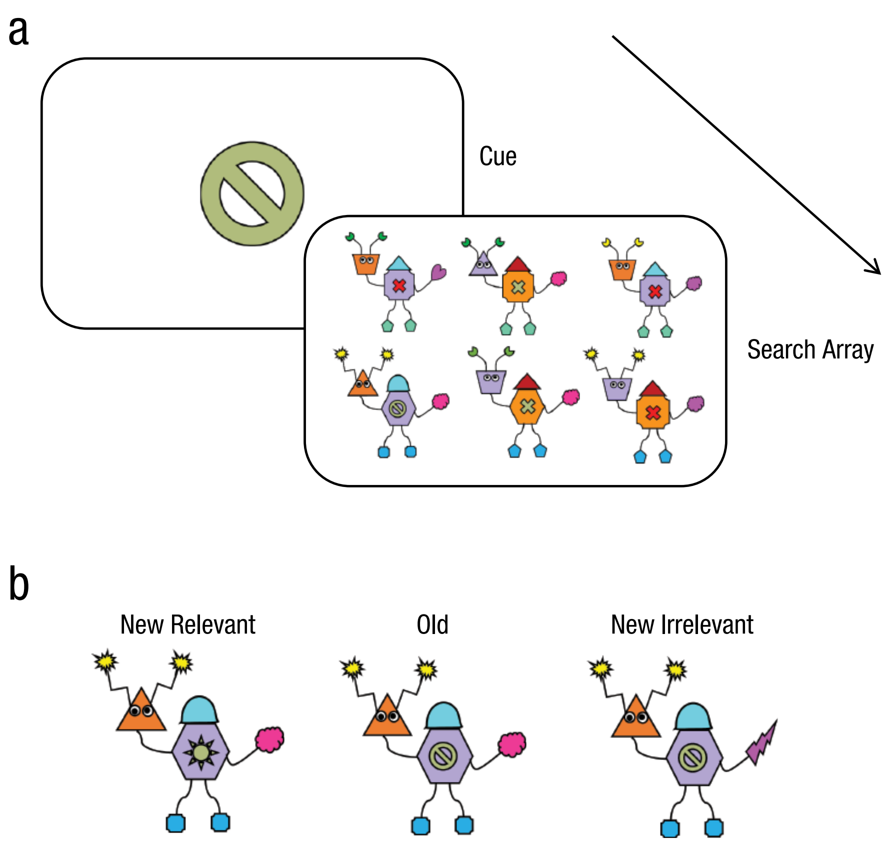

Fig. 3. Illustration of the visual search task and test-trial stimuli in Experiment 2. Each visual search trial (a) began with a cue that identified the target feature. Then the search array was presented, and participants had to find the target. In the test trials (b), old items were ones that had been presented during visual search, whereas new items were created by taking an old item and changing either a relevant or an irrelevant feature.

a set of six objects and asked to find the object that contained the target feature. The adults selected the target object using a computer mouse, whereas the children pointed, and the experimenter entered their responses. No feedback was presented during visual search.

After completing all the visual search trials, participants received 18 recognition trials (6 old, 6 new relevant, and 6 new irrelevant items) for the stimuli in their final search array. Different participants were tested on items from different search sets, and the order of the 18 recognition trials was randomized across participants. On each trial, participants were shown an object and asked if it was a part of the search game or if it was a new item that they had never seen before. As in Experiment 1, we measured accuracy using A'. A' for relevant features was calculated by defining hits as "old" responses to old items and false alarms as "old" responses to new relevant items. A' for irrelevant features was calculated by defining hits as "old" responses to old items and false alarms as "old" responses to new irrelevant items.

High recognition accuracy for new relevant items but not for new irrelevant items suggested that the individual was selectively focusing on only relevant information. Equivalently high memory accuracy for new relevant and new irrelevant items suggested that the individual was distributing his or her attention across both relevant and irrelevant information.

Results

Visual search accuracy. Both the children and the adults performed well in the visual search task and successfully identified the items with the target feature. Although accuracy in both age groups was high (74.5% for the children and 89.2% for the adults) and above the chance level of 16.6% (ps < .001, ds > 6.47), the adults were better at finding the target feature, $t(56) = 3.37$, $p = .001$, $d = 0.91$, 95% CI = [0.38, 1.47]. Therefore, both groups were able to perform the task, though the adults exhibited greater search accuracy than the young children.

Memory for features. Table 2 presents the proportions of "old" responses for the three stimulus types. A 2 (feature type: relevant vs. irrelevant) × 2 (age group: adults

Table 2. Proportion of "Old" Responses for Each Stimulus Type in Experiment 2

	Stimulus type		
Age group	Old (hits)	New relevant (false alarms)	New irrelevant (false alarms)
Adults	.67	.19	.55
Children	.67	.17	.38

vs. children) mixed ANOVA on the A' data (see Fig. 4) revealed a significant interaction, $F(1, 56) = 9.197$, $p = .004$, $\eta^2 = .141$. Specifically, although the adults and children demonstrated comparable recognition accuracy for relevant features (.825 vs. .829), independent-samples $t(56) = -0.109$, $p > .250$, $d = -0.04$, 95% CI = [−0.55, 0.48], the adults had lower accuracy for irrelevant features (.585 vs. .716), $t(56) = -2.651$ $p = .010$, $d = -0.70$, 95% CI = [−1.22, −0.16]. As in Experiment 1, the children exhibited numerically greater net accuracy than the adults (.772 vs. .705), independent-samples $t(56) = -1.918$, $p = .061$, $d = -0.51$, 95% CI = [−1.02, 0.03].

Therefore, as in Experiment 1, a developmental reversal was observed: Children exhibited better recognition of irrelevant features than adults did. Also as in Experiment 1, adults exhibited both benefits of selective attention (i.e., greater visual search accuracy) and costs of selective attention (i.e., less accurate encoding of irrelevant features).

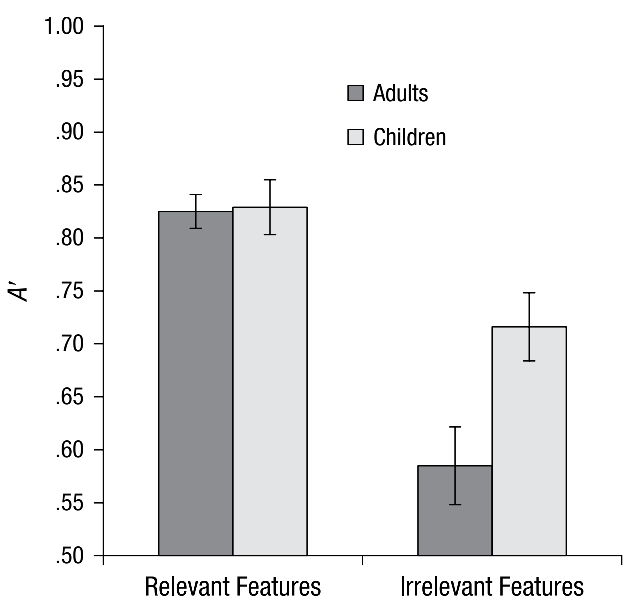

Fig. 4. Recognition accuracy (A') by feature type and age group in Experiment 2. Error bars represent ±1 *SEM*.

General Discussion

These two experiments demonstrated a rare developmental reversal: In change detection and in visual search, 4- to 5-year-olds had a surprising advantage over adults in processing task-irrelevant information. These results provide evidence for costs and benefits of selectivity, thus elucidating developmental changes in selective attention: Whereas mature selectivity provides an advantage in processing task-relevant information, it also impedes processing of task-irrelevant information. These findings have important implications for understanding the development of attention, and cognitive development and learning more broadly.

Developmental reversals and the development of attention

Distributed attention early in development stems from the immaturity of attention-control circuits (Posner & Rothbart, 2007). Compared with more mature selective attention, distributed attention results in greater processing of task-irrelevant information. As the attention-control circuits undergo maturation, the ability to filter out irrelevant information improves (Posner & Rothbart, 2007; Rueda et al., 2005), and this results in both benefits (i.e., more efficient processing of selected information) and costs (i.e., attenuated processing of nonselected information). Specifically, selectivity allows individuals to increase their efficiency in visual search (e.g., Egeth, Virzi, & Garbart, 1984), to focus on a particular information channel (Pashler, 1999), and to learn rule-based categories (Hoffman & Rehder, 2010). However, selectivity reduces the ability to encode unattended information (Rock & Gutman, 1981) and induces learned inattention, which makes future learning more difficult (Hoffman & Rehder, 2010).

It is unlikely that, over the course of development, selective attention completely replaces the ability to attend diffusely; rather, the ability to attend selectively supplements the ability to attend diffusely, becoming a part of an attentional hierarchy. Therefore, under task conditions that tax control circuits (e.g., high working memory load), adults may also exhibit distributed attention (Conway, Cowan, & Bunting, 2001; Lavie, Hirst, de Fockert, & Viding, 2004). Moreover, deterioration of neural circuits controlling selective attention over the course of aging may also result in distributed attention: Older adults are more likely to process task-irrelevant information than younger adults are (Amer & Hasher, 2014). Perhaps younger adults can also distribute attention in a top-down manner when such distribution may benefit their task performance. However, young children are unlikely to exhibit top-down selectivity because they do not have fully developed neural circuits that support selective attention. Therefore, the development of attention is likely to result in greater top-down control over the focus of attention, though this control may weaken under high task demand and deteriorate in the course of aging.

Developmental reversals and cognitive development and learning

Young children's tendency to distribute attention across multiple dimensions has important implications for understanding their performance on many cognitive tasks. For example, the first reports of developmental reversals pertained to memory (Brainerd & Reyna, 2007; Fisher & Sloutsky, 2005; Sloutsky & Fisher, 2004): When presented with items cohering around a particular gist, children are less prone to memory intrusions than adults are. Perhaps because of the immaturity of their selective attention, children process item-specific verbatim information, whereas adults focus primarily on more general gist information.

Similarly, in a category-learning task (Deng & Sloutsky, 2015, 2016), 4- to 5-year-olds' tendency to process information regardless of task relevance resulted in their learning and remembering multiple features of the studied categories. In contrast, adults tended to remember a narrower feature set—the feature set that controlled their categorization.

Distributed attention results in the exploration of a broad set of information rather than a limited focus on a narrow subset and could be particularly beneficial for early cognitive development and learning. Although the tendency to explore broadly may make learning slower, it may also prevent children from learning spurious regularities. Many developmental theorists have identified exploration in childhood as a major contributor to cognitive development (see Loewenstein, 1994, for a review). If the tendency to explore is a by-product of children's difficulty in filtering out "irrelevant" information, the immaturity of early selectivity may actually drive early cognitive development by promoting exploration and broadening processing.

Additionally, children's tendency to distribute attention may affect their learning: Processing of both task-relevant and task-irrelevant information may result in "incidental" learning of more information than is learned when only task-relevant information is processed. Perhaps early educational programs could harness such incidental learning to improve educational outcomes.

Finally, children's tendency to distribute attention may affect their learning in more formal academic settings. Processing both task-relevant and task-irrelevant (or extraneous) information may become a limitation when the goal is to learn rule-based concepts, such as in mathematics and science. In those domains, processing of extraneous information may impede learning of a target concept and its application to novel situations (Kaminski & Sloutsky, 2013; Son, Smith, & Goldstone, 2011). Therefore, reducing extraneous, task-irrelevant information in teaching materials and in the classroom (cf. Fisher, Godwin, & Seltman, 2014) may have a positive effect on early classroom learning.

Conclusions

This study demonstrates an important developmental reversal in the allocation of attention: Children notice what adults tend to miss. Selective attention allows adults to focus on task-relevant information, while ignoring task-irrelevant information. This in turn leads to superior processing of task-relevant information. However, this advantage comes at a cost: Adults encode only a small subset of presented information. In contrast, children lack the attentional control required for selective processing, which results in somewhat inferior processing of task-relevant information, but allows children to ably process task-irrelevant information. These findings have broad implications for understanding early learning and cognitive development.

Action Editor

Kathleen McDermott served as action editor for this article.

Author Contributions

D. J. Plebanek and V. M. Sloutsky designed the research. D. J. Plebanek programmed the experiments and supervised data collection. D. J. Plebanek and V. M. Sloutsky planned the data analyses, and D. J. Plebanek analyzed the data. Both authors wrote the manuscript.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Open Practices

All data and materials have been made publicly available via Harvard Dataverse and can be accessed at http://dx.doi.org/10.7910/DVN/7TA47E. The complete Open Practices Disclosure for this article can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797617693005. This article has received badges for Open Data and Open Materials. More information about the Open Practices badges can be found at http://www.psychologicalscience.org/publications/badges.

References

Amer, T., & Hasher, L. (2014). Conceptual processing of distractors by older but not younger adults. *Psychological Science*, *25*, 2252–2258. doi:10.1177/0956797614555725

Best, C. A., Yim, H., & Sloutsky, V. M. (2013). The cost of selective attention in category learning: Developmental differences between adults and infants. *Journal of Experimental Child Psychology*, *116*, 105–119. doi:10.1016/j.jecp.2013.05.002

Brainard, D. H. (1997). The Psychophysics Toolbox. *Spatial Vision*, *10*, 433–436.

Brainerd, C., & Reyna, V. (2007). Explaining developmental reversals in false memory. *Psychological Science*, *18*, 443–449.

Coch, D., Sanders, L. D., & Neville, H. J. (2005). An event-related potential study of selective auditory attention in children and adults. *Journal of Cognitive Neuroscience*, *17*, 605–622. doi:10.1162/0898929053467631

Conway, A. R. A., Cowan, N., & Bunting, M. F. (2001). The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin & Review*, *8*, 331–335. doi:10.3758/BF03196169

Cowan, N., & Hulme, C. (Eds.). (1998). *The development of memory in childhood*. Hove, England: Psychology Press.

Deng, W., & Sloutsky, V. M. (2015). The development of categorization: Effects of classification and inference training on category representation. *Developmental Psychology*, *51*, 392–405. doi:10.1037/a0038749

Deng, W., & Sloutsky, V. M. (2016). Selective attention, diffused attention, and the development of categorization. *Cognitive Psychology*, *91*, 24–62.

Dunlosky, J., & Metcalfe, J. (2009). *Metacognition*. Thousand Oaks, CA: Sage.

Egeth, H. E., Virzi, R. A., & Garbart, H. (1984). Searching for conjunctively defined targets. *Journal of Experimental Psychology: Human Perception and Performance*, *10*, 32–39. doi:10.1037/0096-1523.10.1.32

Fisher, A. V., Godwin, K. E., & Seltman, H. (2014). Visual environment, attention allocation, and learning in young children: When too much of a good thing may be bad. *Psychological Science*, *25*, 1362–1370. doi:10.1177/0956797614533801

Fisher, A. V., & Sloutsky, V. M. (2005). When induction meets memory: Evidence for gradual transition from similarity-based to category-based induction. *Child Development*, *76*, 583–597.

Hanania, R., & Smith, L. B. (2010). Selective attention and attention switching: Towards a unified developmental approach. *Developmental Science*, *13*, 622–635. doi:10.1111/j.1467-7687.2009.00921.x

Hoffman, A. B., & Rehder, B. (2010). The costs of supervised classification: The effect of learning task on conceptual flexibility. *Journal of Experimental Psychology: General*, *139*, 319–340. doi:10.1037/a0019042

Kaminski, J. A., & Sloutsky, V. M. (2013). Extraneous perceptual information interferes with children's acquisition of mathematical knowledge. *Journal of Educational Psychology*, *105*, 351–363. doi:10.1037/a0031040

Kloos, H., & Sloutsky, V. M. (2008). What's behind different kinds of kinds: Effects of statistical density on learning and representation of categories. *Journal of Experimental Psychology: General*, *137*, 52–72. doi:10.1037/0096-3445.137.1.52

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General*, *133*, 339–354. doi:10.1037/0096-3445.133.3.339

Loewenstein, G. (1994). The psychology of curiosity: A review and reinterpretation. *Psychological Bulletin*, *116*, 75–98.

López, A., Gelman, S. A., Gutheil, G., & Smith, E. E. (1992). The development of category-based induction. *Child Development*, *63*, 1070–1090. doi:10.1111/j.1467-8624.1992.tb01681.x

Markovits, H., & Barrouillet, P. (2002). The development of conditional reasoning: A mental model account. *Developmental Review*, *22*, 5–36. doi:10.1006/drev.2000.0533

Miller, S. A. (1988). Parents' beliefs about children's cognitive development. *Child Development*, *59*, 259–285.

Pashler, H. (1999). *The psychology of attention*. Cambridge, MA: MIT Press.

Pashler, H., Johnston, J. C., & Ruthruff, E. (2001). Attention and performance. *Annual Review of Psychology*, *52*, 629–651.

Plude, D. J., Enns, J. T., & Brodeur, D. (1994). The development of selective attention: A life-span overview. *Acta Psychologica*, *86*, 227–272. doi:10.1016/0001-6918(94)90004-3

Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology*, *58*, 1–23.

Rabi, R., & Minda, J. P. (2014). Rule-based category learning in children: The role of age and executive functioning. *PLoS ONE*, *9*(1), e85316. doi:10.1371/journal.pone.0085316

Rock, I., & Gutman, D. (1981). The effect of inattention on form perception. *Journal of Experimental Psychology: Human Perception and Performance*, *7*, 275–285. doi:10.1037/0096-1523.7.2.275

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2005). The development of executive attention: Contributions to the emergence of self-regulation. *Developmental Neuropsychology*, *28*, 573–594.

Sloutsky, V. M. (2010). From perceptual categories to concepts: What develops? *Cognitive Science*, *34*, 1244–1286. doi:10.1111/j.1551-6709.2010.01129.x

Sloutsky, V. M., Deng, W., Fisher, A. V., & Kloos, H. (2015). Conceptual influences on induction: A case for a late onset. *Cognitive Psychology*, *82*, 1–31. doi:10.1016/j.cogpsych.2015.08.005

Sloutsky, V. M., & Fisher, A. V. (2004). When development and learning decrease memory. *Psychological Science*, *15*, 553–558. doi:10.1111/j.0956-7976.2004.00718.x

Sloutsky, V. M., Kloos, H., & Fisher, A. V. (2007). When looks are everything. *Psychological Science*, *18*, 179–185. doi:10.1111/j.1467-9280.2007.01869.x

Smetana, J. G. (2006). Social domain theory: Consistencies and variations in children's moral and social judgments. In M. Killen & J. G. Smetana (Eds.), *Handbook of moral development* (pp. 119–154). Mahwah, NJ: Erlbaum.

Smith, L. B., & Kemler, D. G. (1977). Developmental trends in free classification: Evidence for a new conceptualization of perceptual development. *Journal of Experimental Child Psychology*, *24*, 279–298. doi:10.1016/0022-0965(77)90007-8

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General*, *117*, 34–50.

Son, J. Y., Smith, L. B., & Goldstone, R. L. (2011). Connecting instances to promote children's relational reasoning. *Journal of Experimental Child Psychology*, *108*, 260–277. doi:10.1016/j.jecp.2010.08.011

Zelazo, P., Müller, U., Frye, D., Marcovitch, S., Argitis, G., Boseovski, J., & Carlson, S. (2003). The development of executive function in early childhood. *Monographs of the Society for Research in Child Development*, *68*(3).