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Brief Report

Endogenously and exogenously driven selective sustained attention: Contributions to learning in kindergarten children



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ABSTRACT

Selective sustained attention is vital for higher order cognition. Although endogenous and exogenous factors influence selective sustained attention, assessment of the degree to which these factors influence performance and learning is often challenging. We report findings from the Track-It task, a paradigm that aims to assess the contribution of endogenous and exogenous factors to selective sustained attention within the same task. Behavioral accuracy and eye-tracking data on the Track-It task were correlated with performance on an explicit learning task. Behavioral accuracy and fixations to distractors during the Track-It task did not predict learning when exogenous factors supported selective sustained attention. In contrast, when endogenous factors supported selective sustained attention, fixations to distractors were negatively correlated with learning. Similarly, when endogenous factors supported selective sustained attention, higher behavioral accuracy was correlated with greater learning. These findings suggest that endogenously and exogenously driven selective sustained attention, as measured through different conditions of the Track-It task, may support different kinds of learning.

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Introduction

Selective sustained attention is the ability to process some parts of the environment at the exclusion of others over a period of time, an ability that has been argued to be fundamental to learning. In particular, selective sustained attention has been implicated in a variety of learning contexts ranging from infants learning their first words (e.g., Smith, Colunga, & Yoshida, 2010; Yu & Smith, 2012) to college students learning in formal education settings (e.g., Wei, Wang, & Klausner, 2012). Despite agreement on the importance of selective sustained attention for human learning and performance, several key theoretical questions about the development of attention, and the relation between attentional processes and learning outcomes, remain unresolved.

One challenge in addressing questions about the relation between attention and learning is the paucity of appropriate experimental paradigms, particularly for preschool-age children. With regard to assessment of selective sustained attention, preschoolers are in a measurement gap; they are too old for the assessment tools used with infants and toddlers, but often they are too young to generate usable data on adult tasks adapted for use with children (e.g., Continuous Performance Task; for a review, see Fisher & Kloos, *in press*). To address this measurement gap, we developed a novel paradigm, the Track-It task (Fisher, Thiessen, Godwin, Kloos, & Dickerson, 2013). In the Track-It task, participants visually track a target moving along a random trajectory on a grid. The target can be accompanied by distractors, also moving along random trajectories. The participants' task is to report the last grid location visited by the target before it disappears.

Prior research with Track-It has primarily focused on disentangling *endogenous* and *exogenous* factors that support selective sustained attention. Exogenous factors relate to characteristics of the stimuli (e.g., contrast, brightness, motion) and are often described in terms of the degree to which a stimulus is "salient." In contrast, endogenous factors are cognitive processes (e.g., active maintenance of representations in working memory, inhibitory control) that allow the organism to voluntarily control the locus of its attention (Colombo & Cheatham, 2006; Kane & Engle, 2002). In newborns and very young infants, selection is typically described as exogenously driven such that the locus of attention is determined largely by physical properties of a stimulus (for reviews, see Bornstein, 1990; Ruff & Rothbart, 2001). Over the course of development, endogenous factors come to play a larger role in selective sustained attention (Colombo & Cheatham, 2006; Diamond, 2006; Oakes, Kannass, & Shaddy, 2002; Ruff & Rothbart, 2001).

In the Track-It task, the contributions of exogenous and endogenous factors are assessed through distractor manipulations. Performance in both distractor conditions is based in part on endogenous factors because the task is not sufficiently engaging that children would perform it in the absence of a request from an adult. Critically, however, the distractor manipulations change the relative importance of the endogenous and exogenous factors in supporting selective sustained attention. Specifically, in the Homogeneous Distractors condition the distractors are identical to each other and different from the target, whereas in the Heterogeneous Distractors condition the distractors are unique from each other and from the target. Tracking accuracy in the Heterogeneous Distractors condition is hypothesized to reflect the contribution of predominantly endogenous factors; the task provides no contextual support to benefit performance (e.g., each object in the set is equally distinct and, therefore, targets are no more salient than distractors), and children need to exert effortful control to remain on-task. In contrast, in the Homogeneous Distractors condition, the target object is distinct and, therefore, more salient than the distractors. Thus, performance in the Homogeneous Distractors condition is hypothesized to reflect the contributions of both endogenous factors (e.g., effortful control because children must still attend to the target and ignore the distractors) and exogenous factors (e.g., due to the higher saliency of target objects compared with distractors).

The ability to sustain attention has long been hypothesized to play a critical role in explicit and implicit learning tasks (e.g., attending to statistical regularities in the input; see Oakes et al., 2002; Perruchet & Vinter, 1998; Thiessen, Kronstein, & Hufnagle, 2013; Wei et al., 2012). At the same time, it remains unclear whether different types of learning tasks are supported by different regulatory mechanisms of selective sustained attention. If different conditions of the Track-It task tap into separate and differentiable factors supporting attention regulation, these conditions should be more or

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