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The role of child socioeconomic status in cognitive training outcomes

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ABSTRACT

Socioeconomic status (SES) has been shown to influence children's executive function and cognitive function more generally, and may play a role in one's ability to benefit from a cognitive or academic intervention. However, SES remains largely unstudied in the context of computerized cognitive training. Here we draw from two datasets of 6–18 year-old children completing online cognitive training to examine the impact of SES on executive function. The first study utilizes hierarchical linear modeling to examine how school-level free/reduced-price lunch status relates to executive function following cognitive training. The second study focuses on individual-level free/reduced-price lunch status and adds an active control condition. Both studies find that free/reduced-price lunch status and age are associated with improvements in executive function following training. However, there were no interaction effects between SES and condition, suggesting that there is little difference in how children from different SES groups benefit from computerized cognitive training.

1. Introduction

Significant attention has been paid to the role of socioeconomic status (SES) on the cognitive development of children and adolescents. SES is generally characterized by family income, occupation, and/or education (Entwisle & Astone, 1994) and has a sizeable effect on capacities associated with the prefrontal cortex, including executive function and working memory. The effect of SES on prefrontal function tends to be larger in magnitude than the effect on many other brain regions (Evans & Schamberg, 2009; Farah, Noble, & Hurt, 2009; Hackman & Farah, 2009; Hackman, Farah, & Meaney, 2010; Noble, McCandliss, & Farah, 2007; Sarsour et al., 2011). SES does not in and of itself impact the development of prefrontal functioning. Rather, associated factors, including parental warmth, physical environment, cognitive stimulation, physical activity/physical fitness, adiposity, nutritional deprivation, exposure to neurotoxins, anxiety, depression, stress, and trauma are likely responsible for these effects (Canfield et al., 2003; DePrince, Weinzierl, & Combs, 2009; Diamond & Lee, 2011; Eysenck, Derakshan, Santos, & Calvo, 2007; Fay-Stammbach, Hawes, & Meredith, 2014; Lawson et al., 2014; Lukowski, Koss, & Burden, 2010; Pollack, Griffin, & Lynch, 2010; Rogers et al., 2004; Sarsour et al., 2011; Valiente, Lemery-Chalfant, & Reiser, 2007).

In general, children with parents from higher SES backgrounds perform better on measures of prefrontal function, such as the go/no-go test and the spatial memory span test, than their peers with parents from lower SES backgrounds (Noble, Norman, & Farah, 2005). These disparities in behavioral performance are accompanied by SES-related differences in children's brain structure as well (Noble et al., 2015). SES may also be related to performance on other cognitive measures that are often associated with executive function but are not typically considered to be under the umbrella of executive processes per se, such as speed of processing (Buckhalt, El-Sheikh, & Keller, 2007), as well as more domain specific skills with a strong executive component, such as math (Duncan & Magnuson, 2012).

1.1. SES and executive function plasticity

Although a variety of studies have examined the impact of parental-SES on executive function and related cognitive skills, most of these studies have focused on performance at a single time-point. Given that cognitive processes such as working memory develop throughout childhood and early adulthood (Klingberg, Forssberg, & Westerberg, 2002; Romine & Reynolds, 2005) and that life experience and interventions impact this development (Zelazo & Carlson, 2012), one important question is the extent to which the improvement or learning of these processes, rather than performance at a single time point, may be impacted by SES. This question has practical relevance because performance on executive function-related cognitive tasks is highly associated with academic and life outcomes (Best, Miller, & Naglieri, 2011; Moffitt et al., 2011).

There are three logical possibilities regarding the influence of SES on learning executive function tasks such as working memory and

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inhibitory control. Given that children from low-SES backgrounds may have received less of the cognitive stimulation that might support the development of executive functions (Farah et al., 2008; Votruba-Drzal, 2003), interventions that provide that stimulation might be especially beneficial for those children. Alternatively, the factors that led to relative deficits in executive functions might also lead to reduced improvement. For example, stress is one factor that negatively affects executive function (Arnsten, 2015; Liston, McEwen, & Casey, 2009; Taylor, Eisenberger, Saxbe, Lehman, & Lieberman, 2006); it is possible that experiencing stress may also negatively impact one's ability to *benefit* from an executive function intervention (Diamond & Ling, 2016). Finally, it is possible that both high- and low-SES children benefit equally from executive function interventions, with the primary difference being performance at baseline.

1.2. Recent studies of SES and cognitive training

A variety of studies have examined the effects of cognitive training on working memory and executive function in children (e.g., Diamond, Barnett, Thomas, & Munro, 2007; Klingberg et al., 2005), and cognitive training remains a potential means of improving executive function performance among individuals from low-SES backgrounds. These training interventions vary widely in design and methodology, but generally, they include a variety of cognitive activities or games that may increase in difficulty as individuals improve. However, while some of these studies have been conducted with low-SES populations (e.g. Mezzacappa & Buckner, 2010), very few of them systematically evaluate the relationship between SES and the outcome of the intervention. It is also possible that factors related to SES, such as prior access to technology, will play a different role in an intervention that is computer-based versus one that is not. For example, with computer-based interventions there may be less one-on-one facilitator time to help students who are struggling to complete the program. Thus findings from research on how SES impacts the outcome of computerized cognitive training may be highly relevant in advancing our understanding of the practical significance of these interventions.

Two recent studies have directly compared the effectiveness of cognitive interventions for children from different SES backgrounds. One is a large-scale (N = 759) cluster-randomized study of a childhood intervention used in kindergarten classrooms, Tools of the Mind, which is a teacher-led early childhood curriculum that focuses on self-regulation and executive-function activities (Blair & Raver, 2014). Blair and Raver found positive improvements in executive function and reasoning compared to a passive control group. Additionally, they found that children from high-poverty schools benefited from Tools of the Mind far more than low-poverty children, at least for some outcome measures. Based on these findings, the authors suggest that Tools of the Mind may serve as a helpful tool for reducing the achievement gap.

Another study of reasoning training with a large number of middle school students (N = 913) found similar improvements in reasoning ability following training for both high- and low-SES children (Gamino et al., 2014). Gamino et al. utilized a reasoning intervention that included a battery of individual and group pen and paper reasoning strategy exercises (for example, some of the exercises helped students focus on relevant factors and ignore irrelevant factors in a reasoning problem; some focused on paraphrasing skills, and so forth). Both of these studies provide some early evidence that SES does not pose a significant impediment to benefiting from a cognitive training intervention. Furthermore, these studies suggest that similar dosage and styles of intervention may be efficacious for children regardless of SES level, and may even be *more* effective for those from impoverished backgrounds.

1.3. SES and computerized cognitive training

Here we present the results of two studies that extend these findings. Study 1 examines the outcome of computerized cognitive training within as a function of school-level SES in a large, national sample of students ages 6–18. Study 2 examines this intervention with a smaller group of students and includes an individual-level measure of SES. We note that both studies took place in school environments with the intervention administered by regular classroom teachers who volunteered for the study (a context that somewhat limits the generalizability of the results). Lumos Labs, Inc., the creators of the cognitive training website Lumosity.com, provided the data used for independent analysis and the company exerted no editorial control over the findings presented here.

The intervention used in these studies differs from the ones used by Blair and Raver (2014) and Gamino et al. (2014) in that it is a computerized cognitive intervention that, although widely used, has not been studied extensively with children. This computerized intervention is comprised of several executive function-demanding games designed to improve prefrontal function (Hardy et al., 2015). Like Gamino et al., the present studies included somewhat older children than those in the Blair and Raver study.

Importantly, it is also possible that the benefits of cognitive training are moderated by age. Extant research suggests that certain cognitive capacities, including working memory and inhibitory control, improve from early childhood into adolescence (Brocki & Bohlin, 2004; Heyes, Zokaei, & Husain, 2016). However, while there is a substantial body of evidence that suggests that one's ability to improve these capacities may also change with age, most of this research is with adults, and older adults in particular (Morrison & Chein, 2011; Schmiedek, Lövdén, & Lindenberger, 2010). Thus age is also a variable of substantial interest, particularly within Study 1, given that it includes a fairly large age band of participants.

The current state of computerized cognitive training research is such that transfer effects, when they are found, are generally near in nature (Diamond & Ling, 2016; Melby-Lervåg, Redick, & Hulme, 2016). While some studies have demonstrated significant improvement on untrained tasks following a working memory or executive-function intervention (Blair & Raver, 2014; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Klingberg et al., 2005), many others have found no such improvements (Redick et al., 2013; Roberts et al., 2016; Thompson et al., 2013). We have proposed that one potential reason for this inconsistency may be that the populations tested in studies differ in terms of age, motivation, experience with technology, and socioeconomic status. In addition to shedding light on the connection between SES and the outcome of cognitive training, the present research may also help explain why the findings from these cognitive training studies remain so inconsistent. Finally, to be clear, we note that the primary goal of the current analysis is not to examine the effectiveness of cognitive training per se, but rather to focus on the potential impact of SES on improvements following training. These data cannot provide solid evidence regarding the potential for far transfer: Study 1 did not include an active control group, Study 2 involved a relatively small dose of training, and the outcome tasks included here are arguably measures of near, rather than far, transfer.

1.4. Study 1

The goal of Study 1 was to examine how school-level socioeconomic status is related to changes in executive function following a computerized cognitive training program. As discussed above, this dataset was provided by Lumos Labs, Inc. and included data from a large nationally-distributed sample of American schoolchildren. In this study, schools were randomly assigned to a cognitive training intervention group or a passive control group. All children were administered a battery of executive-function tasks prior to the intervention and again following the intervention. The cognitive training intervention included a variety of games focused on working memory, task-switching, and response inhibition.

Study 1 focuses on a school-level measure of SES. As discussed