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A systematic assessment of socioeconomic status and executive functioning in early childhood

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ABSTRACT

Lower socioeconomic status (SES) consistently relates to poorer executive function (EF). This study used a systematic and nuanced approach to understand how SES relates to children's EF at a process level. We assessed children aged 4.5–5.5 years. This is a key developmental period because EF is no longer a unitary construct but rather EF components statistically load on separate factors and index distinct aspects of EF. Children completed a working memory task that involved a cognitive load component and a go/no-go task to assess inhibitory control and vigilance. Accuracy and reaction time were assessed, and each task involved four blocks to assess performance over time. Lower SES related to lower accuracy for working memory, inhibitory control, and vigilance as well as slower reaction time for working memory. SES did not relate to go/no-go reaction time. For working memory, lower SES related to poorer accuracy on lower cognitive load trials, but there were no SES differences on higher cognitive load trials. SES did not relate to maintenance of performance over time. Results suggest that for this age group the majority of domains showed SES differences. However, there were no SES differences in performance for remembering two items and maintaining performance. Thus, although overall lower SES related to poorer EF performance, there were no SES effects for skills that are still emerging for all children, namely, maintaining task performance across time and remembering two items at once. Results highlight the importance of assessing EF as a multidimensional construct and may help to identify targets for intervention.

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Introduction

It is well established that socioeconomic status (SES) predicts children's executive functioning (EF) such that lower SES is associated with poorer EF (Lawson, Hook, & Farah, 2017). However, although EF is a construct encompassing multiple higher-order cognitive processes, the majority of studies use only composite accuracy scores to assess how SES relates to EF (Dilworth-Bart, 2012; Hackman, Gallop, Evans, & Farah, 2015; Noble, McCandliss, & Farah, 2007; Raver, Blair, & Willoughby, 2013). This approach masks potential nuance in assessing SES–EF relations. SES does not have global effects on cognitive functioning but particularly affects EF (Farah et al., 2006; Hackman & Farah, 2009; Noble et al., 2007; Noble, Norman, & Farah, 2005). Likewise, given that EF is multidimensional, it is possible that SES may also differentially relate to aspects of EF. However, a nuanced approach has not yet been used to systematically assess the scope of how SES relates to different facets of EF in early childhood. For example, studies have assessed how SES relates to a composite accuracy measure of working memory, a component of EF (Farah et al., 2006; Hackman et al., 2014; Noble et al., 2005, 2007; Sarsour et al., 2011), but not how SES relates to the cognitive load aspect of working memory. In addition, most studies assess EF based on accuracy and do not consider the role of processing speed. The speed at which children process information is indicative of white matter development and organization (Ferrer et al., 2013) and is correlated with EF performance (Mulder, Pitchford, & Marlow, 2011; Rose, Feldman, & Jankowski, 2011). Because processing speed demands are embedded in many EF tasks, it is important to examine processing speed as a parallel construct to children's EF. Furthermore, how SES relates to the capacity to sustain performance across time on an EF task remains largely unexplored. Expanding our knowledge and providing specificity of SES effects on EF matter from a theoretical perspective to move away from a global deficit model of development. It is also important from an intervention perspective to better understand which aspects of EF may or may not be affected by SES. This study worked to fill this gap and examine how SES relates to multiple facets of EF in early childhood.

EF encompasses complex goal-directed and regulatory processes (Anderson, 2002; Best & Miller, 2010; Diamond, 2013). EF is crucial for many life outcomes, including school success, health, and quality of life (for a review, see Diamond & Ling, 2016). An important period of EF development occurs between 3 and 6 years of age (Carlson, 2005). The skills gained during this period are essential because they set the stage for school readiness as children enter kindergarten such that children with poor EF are at risk for academic difficulties (Allan, Hume, Allan, Farrington, & Lonigan, 2014; Fuhs, Nesbitt, Farran, & Dong, 2014; Willoughby, Kupersmidt, & Voegler-Lee, 2012).

EF is composed of multiple factors, two of which are working memory and inhibitory control (Best & Miller, 2010; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Working memory is defined as holding information in mind while performing mental operations (Baddeley & Hitch, 1974; Repovš & Baddeley, 2006). Working memory is necessary for reasoning and problem solving given that both of these processes require holding information in mind while thinking about it in different ways (for a review, see Diamond & Ling, 2016). Inhibitory control refers to the inhibition of a dominant response (Diamond, 2013) and is a key skill for goal-directed behavior because one needs to inhibit initial impulses when working toward a goal. Working memory and inhibitory control are critical in a school environment because children must be able to hold information in mind as they are given directions throughout the course of a day as well as inhibit their chosen responses in favor of paying attention.

A significant developmental period to assess working memory and inhibitory control in children is between 4 and 6 years of age. Prior to this time, EF has been shown to be a unitary construct (Wiebe, Espy, & Charak, 2008; Wiebe et al., 2011). However, by 4 or 5 years of age, working memory and inhibitory control statistically load on separate factors (Monette, Bigras, & Lafrenière, 2015; Simanowski & Krajewski, 2017). Thus, although they both are aspects of EF, they are indexing distinct constructs. Further research suggests that these two aspects of EF may be differentially linked to academic skills (Allan et al., 2014; Fuhs et al., 2014; Lubin, Regrin, & Boulc'h, L., Pacton, Lanoë, 2016; Simanowski & Krajewski, 2017). Working memory matters for reading abilities (Loosli, Buschkuehl, Perrig, & Jaeggi, 2012; Lubin et al., 2016; Peng et al., 2018; Titz & Karbach, 2014), and inhibitory control is

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linked more strongly to math skills than to literacy skills (Allan et al., 2014). Therefore, EF shows unity, such that performance on components of EF tends to be correlated, but also shows diversity, such that different components of EF index different functions (Friedman & Miyake, 2017).

Given that EF significantly develops in early childhood and EF during this period predicts academic achievement, it is important to understand factors that help or hinder EF development. One critical source of limitation on EF is SES. SES refers to a complex multidimensional construct that reflects financial resources and capital, with the most common indicators of SES being household income, parental education, and parental occupation (Hackman & Farah, 2009; Ursache & Noble, 2016). Lower SES is associated with many adverse outcomes, including poorer health, poorer psychological well-being, and worse scores on measures of academic achievement (for a review, see Bradley & Corwyn, 2002; Hackman, Farah, & Meaney, 2010). Research also consistently demonstrates that lower SES is associated with poorer EF (Farah et al., 2006; Hackman et al., 2015; Lawson et al., 2017; Noble et al., 2005, 2007; Sarsour et al., 2011). Furthermore, this relation is present in early childhood such that already by school entry lower-SES preschoolers have worse behavioral performance on EF tasks compared with their higher-SES peers (Farah et al., 2006; Hackman et al., 2015; Raver et al., 2013).

SES does not only matter for children's EF within the context of poverty; a recent meta-analysis showed that SES differences in EF are evident across the SES spectrum when assessed continuously (Lawson et al., 2017). Academic achievement also varies across the SES spectrum, with marked disparities not only for children in poverty but also between the middle and upper classes (Reardon, 2011). EF has been proposed and empirically demonstrated to be a mediator between SES and academic outcomes (Dilworth-Bart, 2012; Lawson & Farah, 2017; Nesbitt, Baker-Ward, & Willoughby, 2013). Understanding the nuances of how SES relates to multidimensional assessments of EF could elucidate the mechanisms underlying these associations, help to inform research moving forward to develop targeted interventions to improve child EF, and ultimately contribute to narrowing socioeconomic achievement gaps. Thus, it is important to deepen our understanding of the nature of SES–EF relations by using nuanced assessments and by including a sample that includes the range of SES to better understand how SES relates to EF on a continuum.

Pioneering work showed that SES has specific effects on EF compared with other aspects of cognition (Farah et al., 2006; Noble et al., 2005). Specifically, researchers demonstrated that when comparing groups of low-SES and high-SES children, SES was more associated with aspects of EF including memory and inhibitory control than with visual and spatial cognition (Farah et al., 2006; Noble et al., 2005). However, there are multiple limitations of this past research. For instance, most studies assessing SES–EF relations in early childhood have included either a composite of overall EF (Raver et al., 2013) or one score for each EF component based on task accuracy (e.g., one score for working memory and one score for inhibitory control) (Hackman et al., 2015; Noble et al., 2005, 2007). Although these studies were essential for initially demonstrating SES effects on EF, less is known about how SES may relate to specific aspects of these EF components. For example, one accuracy score for working memory does not provide information on how SES may relate to working memory when holding more or fewer objects in mind. Given that EF is a multidimensional construct, with each construct relying on multiple processes, aspects of EF may be differentially affected by SES.

First, whereas previous work has examined the relation between SES and working memory, no studies have assessed how SES relates to variation in working memory capacity, which refers to how many items can be retained in working memory. There is variation in working memory capacity with development such that children can retain more items with age (for reviews, see Cowan, 2016, and Kibbe, 2015; Simmering, 2012). If lower SES is related to a delay in this developmental progression, then one might expect SES to relate to children's performance on a working memory task differentially depending on the cognitive load demands. Specifically, SES may more strongly relate to children's performance when children need to retain more items in working memory such that higher SES relates to better performance when remembering more items, with smaller or no SES effects on performance when remembering fewer items. This may suggest that SES is relating to the acquisition of more challenging working memory processes. Alternatively, it is possible that SES may have more pronounced associations with working memory when cognitive load is low, reflecting a potential delay in basic working memory processes.

With respect to inhibitory control, numerous studies have used the go/no-go task (Noble et al., 2005, 2007). In this task, children are told to press a button for all stimuli (go trials) but to withhold pressing the button for certain test stimuli (no-go trials). The no-go trials index inhibitory control because children need to inhibit their prepotent response to press the button (Lewis, Reeve, Kelly, & Johnson, 2017; Noble et al., 2005). Conversely, the go trials index sustained attention or general vigilance (Lewis et al., 2017; McDermott, Westerlund, Zeanah, Nelson, & Fox, 2012). Given that these different trial types index differing cognitive demands, they can each provide information on aspects of children's EF. However, past studies that examined effects of SES on inhibitory control have focused on results for the no-go trials (Noble et al., 2005, 2007). To provide greater specificity of SES effects on both inhibitory control and general vigilance, performance on both no-go trials and go trials should be assessed and interpreted.

Second, many studies assessing how SES shapes EF in early childhood have solely assessed children's accuracy and have not considered reaction time (Dilworth-Bart, 2012; Hackman et al., 2015; Noble et al., 2007; Raver et al., 2013). EF indexes broad higher-order cognitive functions underlying goal-directed behavior. Reaction time is important to consider because there may be trade-offs in processing speed and EF performance (Best, Miller, & Naglieri, 2011; Davidson, Amso, Anderson, & Diamond, 2006). For example, a child may maintain accuracy by slowing down or, conversely, could maintain speed but lose accuracy. Thus, processing speed, as measured by reaction time, is embedded in performance in EF tasks and is important to consider within the context of SES. Including measures of both children's accuracy and reaction time can provide specificity and a better understanding of how SES may relate to both of these performance indices.

Third, no studies to our knowledge have assessed how children's EF performance may change throughout the course of a task and how SES may relate to this potential change in performance. EF tasks inherently require attention and the ability to maintain performance across time. Although attention and EF have been measured in the same studies, they are typically assessed with separate tasks (Friedman et al., 2007; Reck & Hund, 2011). Thus, no studies have considered focus and maintenance of performance that are embedded within EF tasks. This is a critical factor to consider because SES differences in a composite accuracy score could in part reflect loss of focus and result in a quicker decline in performance throughout the course of an EF assessment. Thus, low performance on a working memory task could result from a deficit in working memory, or it could result from a loss of focus and ability to maintain performance over time. Therefore, assessing children's performance on the specific EF skills (e.g., working memory, inhibitory control) as well as change in their performance throughout a task is key to help clarify the source of SES differences in composite accuracy measures. Furthermore, EF is an essential skill for children in a school environment where EF demands are placed on children throughout the course of the day. Thus, it is especially important to understand how SES may relate to children's ability to maintain EF performance throughout the course of a task.

In sum, there are three gaps in the literature that need to be addressed to better understand how SES relates to EF in early childhood. First, past studies have used composite accuracy measures that did not distinguish among factors such as cognitive load and trial type. Thus, it is not known whether SES is related to global differences in EF accuracy or whether these differences are evident only under certain conditions. Second, studies typically measure only accuracy and do not include reaction time measures. Therefore, it is unclear how SES also relates to processing speed. Lastly, no studies to our knowledge have assessed how children's EF performance may change throughout the course of a task and how SES may relate to this potential change in performance. Given the importance of EF for school readiness and academic success, characterizing the scope and nature of SES differences in early childhood EF is a critical step toward addressing the socioeconomic achievement gap.

The current study

The goal of the current study was to examine how SES relates to multiple aspects of working memory and go/no-go tasks in a sample of 4.5- to 5.5-year-old children. We focused on this age range because this is the time frame when EF components are no longer a unitary construct but rather statistically load on separate factors (Monette et al., 2015; Simanowski & Krajewski, 2017) and it is a period of development for working memory capacity (Simmering, 2012). First, we assessed whether the

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relation between SES and performance on these measures varied by cognitive load in a working memory task and by trial type in a go/no-go task, with no-go trials indexing inhibitory control and go trials indexing general vigilance. Second, we explored how SES related to both accuracy and reaction time on each of these measures. Third, we assessed whether SES related to capacity to maintain performance over time during these tasks. We characterized SES using a multidimensional assessment that included indices of income, parent education, and parent occupational prestige.

Prior literature shows that children's accuracy declines as children retain more items in working memory (Buss, Fox, Boas, & Spencer, 2014; Riggs, McTaggart, Simpson, & Freeman, 2006; Simmering, 2012). Therefore, we expected that SES would interact with cognitive load on the working memory task such that SES would have a stronger relation to performance on more difficult trials (i.e., when children needed to remember two items), with less pronounced SES differences on easier trials (i.e., when children needed to remember only one item). In the go/no-go task, we expected that SES would relate to accuracy on both no-go trials (indexing inhibitory control) and go trials (indexing general vigilance). Given that little research has assessed how SES relates to children's processing speed, reaction time analyses were exploratory. Lastly, we hypothesized that SES would relate to maintenance of performance across the time course of the tasks such that lower SES would relate to a steeper decline in performance.

Method

Participants

Participants were 121 children (70 girls) aged 4.5–5.5 years and their primary caregivers. Children spoke and understood English. Children were full-term singletons with no known hearing, visual, neurological, or developmental disorders (see Table 1 for demographic information). An additional 4 children enrolled in the study but were not included in analyses due to their declining to participate in both of the tasks ($n = 3$) or not understanding both tasks ($n = 1$).

An effort was made to recruit an economically diverse sample across the SES spectrum. Thus, 44.17% of the sample ($n = 53$) was at or below an income-to-needs (ITN) ratio of 3.0, meaning that these children's families had an income less than three times the federal poverty line given their household size. Given the high cost of living in the city where this study was conducted, an income below the threshold of 3 times the federal poverty line is considered financially strained (Ames, Lowe, Dowd, Liberman, & Youngblood, 2013). Specifically, for a four-person household in the city where the study was conducted, an income of $73,776 is needed to meet basic needs (Ames et al., 2013). Furthermore, the median income for the city in which the study was conducted is $102,757 (Census American Community Survey, 2016). The federal poverty line for a family of four is

Table 1
Demographics.

Maternal age [years, *M* (*SD*)]	36.20 (5.30)
Paternal age [years, *M* (*SD*)]	39.32 (7.19)
Child age [years, *M* (*SD*)]	5.02 (0.29)
Child ethnicity (%)	
White	43.00
Black	12.40
Hispanic/Latino	11.60
Asian	10.70
Multiracial/Other	22.30
Income-to-needs ratio [*M* (*SD*)]	4.37 (3.84)
Maternal education (% with at least a 4-year college degree)	70.25
Paternal education (% with at least a 4-year college degree)	62.71
Maternal occupational prestige [1–5 scale, *M* (*SD*)]	3.28 (1.26)
Paternal occupational prestige [1–5 scale, *M* (*SD*)]	3.50 (1.07)

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Table 2
ITN and parent education information.

ITN grouping	Frequency	%	Cumulative %
0.00–1.00	20	16.67	16.67
1.00–2.00	14	11.67	28.34
2.00–3.00	19	15.83	44.17
3.00–4.00	13	10.83	55.00
4.00–5.00	14	11.67	66.67
5.00–6.00	10	8.33	75.00
6.00–7.00	10	8.33	83.33
7.00–8.00	4	3.33	86.66
8.00–9.00	4	3.33	90.00
9.00–10.00	3	2.50	92.50
>10.00	9	7.50	100
Maternal education			
Some middle school or some high school	5	4.13	4.13
High school graduate or GED	8	6.61	10.92
Some college	23	19.00	29.92
4-year college degree	31	25.62	55.54
Graduate degree	54	44.63	100.00
Paternal education			
Some middle school or some high school	6	5.08	5.08
High school graduate or GED	19	16.10	21.18
Some college	19	16.10	37.28
4-year college degree	23	19.49	56.77
Graduate degree	51	43.22	100.00

Note. ITN, income-to-needs ratio. This refers to the level of a household's income relative to the federal poverty line. Thus, an ITN of 1.00 means that a family has an income at the federal poverty line, an ITN of 2.00 means that a family has an income 2 times that of the federal poverty line, and so on.

$24,600, and a household whose members make 3 times this amount would total to $73,800. Thus, a family whose members make less than 3 times the federal poverty line is an approximation of who is considered financially strained in this sample. The median ITN of the sample was 3.39. For further breakdown of the income distribution of the sample, see Table 2.

General procedure

Participants were recruited from a department-maintained database of families interested in research, from publicly available state birth records, from online advertising, and through face-to-face-recruitment events at Head Start programs, diaper banks, community play groups, and a community health center. This study was approved by the university institutional review board. Parent–child dyads visited the laboratory for one session lasting 1.5–2.0 h. Following informed consent, the experimenter presented the child with a sticker card with the child's name on it and explained that by working hard at the games, the child could earn stickers. The child then completed computerized working memory and go/no-go tasks. Tasks were administered via E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA, USA). Lastly, the parent completed a demographics questionnaire.

Measures

Children completed a working memory task and a go/no-go task. We designed these tasks to tease apart at a process level how SES relates to EF in children. We also worked to reduce verbal demands and social interaction. To assess multiple dimensions of EF, we administered both tasks on a computer, which allowed us to measure both accuracy and reaction time. In addition, the block design allowed us to test not only for overall performance but also children's ability to maintain performance over time. Given the relevance of SES differences in vocabulary and language skills (Noble et al., 2007; Sarsour et al., 2011), children were able to complete both tasks with a response pad to help minimize

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children's verbal ability as a confound. Finally, computer administration was also chosen to limit possible effects of interaction with the experimenter given the role of social interaction for the development of EF (Moriguchi, 2014).

Working memory

Children completed an adapted version of a change detection task (Luck & Vogel, 1997; Riggs et al., 2006; Simmering, 2012) (see Fig. 1). This task was chosen because it has been established as a measure of working memory capacity in children of this age, because it has been shown to reveal developmental change across the tested age range, and because it is a relatively pure measure of working memory that does not make significant demands of other EF processes. For each trial, children saw either one or two 1-inch colored squares (1000 ms). The colors of the squares on each trial were randomized, and the same colors were not repeated within each trial. Children then saw a blank screen (1100 ms). Finally, one color was presented in the middle of the screen (test) and children had 5 s to respond whether they had seen the color before. Children responded by pressing one of two buttons on a response pad: a green "thumbs up" for "yes" or a red "thumbs down" for "no." Following each trial, a fixation cross was presented for a randomized intertrial interval ranging from 500 to 1500 ms.

Set sizes 1 and 2 were chosen for this task based on past research (Simmering, 2012) and piloting. Previous work has shown that there is variability in performance on these set sizes at 4 and 5 years of age (Simmering, 2012). In addition, we pilot tested our version of the change detection task to ensure that both low- and high-SES children could understand the task and that we could obtain sufficient variability in performance (e.g., there were no floor or ceiling effects). We found that performance at set size 3 was not different from chance, whereas the majority of children in pilot testing performed above chance (but not at ceiling) on set sizes 1 and 2.

The experimenter first practiced the task with the child with laminated cards to ensure that the child understood the task, per the recommendation from researchers who have used similar tasks (Simmering, 2012). Next, the experimenter introduced the response buttons, and the child completed 19 practice trials on the computer.

In the task, children completed a total of 160 trials, broken down into four blocks of 40 trials. There were 80 trials per set size (1 or 2), and trial set size was randomized within each block. To provide motivation to complete the task, children were told that an elephant, Snickers, was lost in Candyland and needed their help. By remembering colors, they moved Snickers along the path to Candy Castle. They saw the map of Candyland at the beginning of the task and again after each block, so they could

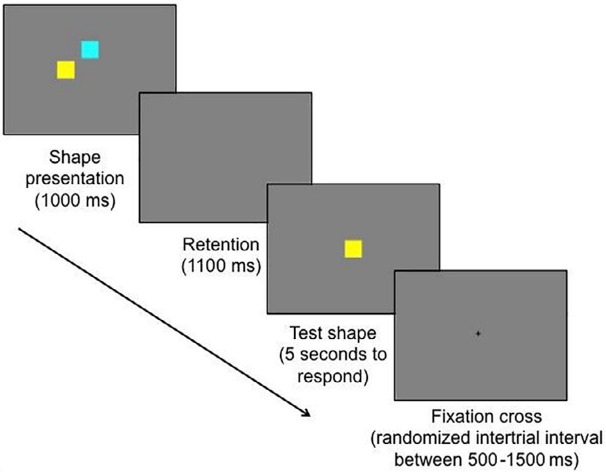

Fig. 1. Visual depiction of the working memory task. The figure shows a set size 2 trial.

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see the progress of Snickers moving closer on the path back to Candy Castle. Children received two stickers after each block to encourage task compliance.

Accuracy and reaction time were computed for each set size and block. Accuracy was the proportion of correct responses. Reaction time was calculated as the mean reaction time on correct trials only. Trials with reaction times < 150 ms were excluded prior to computing the mean reaction time. We excluded trials with reaction times < 150 ms on the basis that it was too quick for children to have actually processed the new stimulus. Thus, children could get the trial correct by chance just by hitting the button quickly. Thus, on these trials it was likely an impulsive response where children did not have time to fully process the stimuli. To ensure that only children who understood the task were included in working memory analyses, children needed to perform above chance on overall accuracy ($\geq .57$, binomial $p < .05$), and 95 children (78.51%) met this criterion. An additional child declined to complete the task. There was a difference in SES when comparing the children who performed above and below chance such that children who performed above chance were higher SES than children who performed below chance, $t(118) = -2.31$, $p = .023$. Of children who performed above chance on set size 1, 92 completed all four blocks. The entire task took about 20 min to complete.

Go/No-go

Children completed a go/no-go task (He et al., 2010; Lamm et al., 2014). Children were told that all of the animals had escaped from their cages at the zoo and the zookeeper needed their help to catch them (see Fig. 2) but that the friendly orangutans are helping them catch the animals. Therefore, children were told to press a button to catch the animals each time they saw an animal (go trial) but not to press the button when they saw an orangutan (no-go trial). Therefore, children needed to inhibit their dominant responses on no-go trials. Children completed 18 practice trials, and the rules were repeated halfway through the task. Each trial was preceded by a fixation cross with a randomized intertrial interval between 200 and 300 ms. The animal stimuli were presented for 750 ms and were followed by a blank screen for 500 ms. Children could respond during the presentation of the stimulus or on the blank screen.

Children completed a total of 280 trials, of which 75% were go trials and 25% were no-go trials. The trials were broken up into four blocks. Children were shown a map of the zoo at the beginning of the task and after each block so that they could track their progress. As in the working memory task, children received two stickers at the end of each block. Accuracy was computed for each trial type (go and no-go) and block. Reaction time was calculated as the mean reaction time on correct go trials only. Trials with reaction times < 150 ms were excluded prior to computing the mean reaction time. The

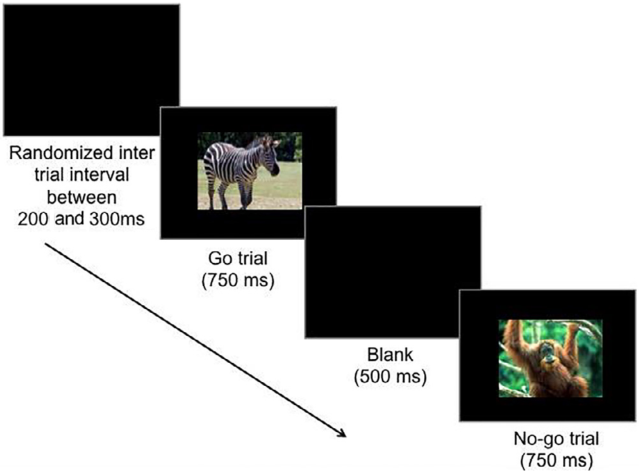

Fig. 2. Visual depiction of the go/no-go task.

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Table 3
Task descriptive statistics.

	M (*SD*)	Min	Max	*N*
Accuracy overall working memory	.77 (.11)	.57	.99	95
Reaction time overall working memory (ms)	1737.50 (290.02)	1106.04	2444.14	95
Accuracy set size 1	.80 (.13)	.55	1.00	95
Accuracy set size 2	.75 (.11)	.48	.99	95
Reaction time set size 1 (ms)	1687.97 (297.31)	1000.22	2409.94	95
Reaction time set size 2 (ms)	1790.89 (305.61)	1202.10	2475.89	95
Accuracy in go trials	.90 (.07)	.65	1.00	117
Accuracy in no-go trials	.64 (.20)	.11	.99	117
Reaction time in accurate go trials (ms)	643.47 (72.30)	385.82	816.84	117

no-go trials index inhibitory control only if children understand the task and are sufficiently engaged in it to have an impulse to push the button on no-go trials. To ensure that only children who understood and were attempting to follow the rules were included, children were excluded if they met the following criteria: go accuracy was less than 70% and no-go accuracy was higher than go accuracy. Three children met this criteria and were excluded from go/no-go analyses. An additional 2 children declined to complete the task. Of 117 children who were included in analyses, 105 completed all four blocks of the task. There was no SES difference when comparing children who completed four blocks compared with children who completed less than four blocks. The task took about 12 min to complete. See Table 3 for descriptive statistics of both study tasks.

Socioeconomic status

The parent reported highest maternal and paternal educational level, household income, household composition, and maternal and paternal occupation. An ITN ratio based on the federal poverty level was computed with income and household composition. Occupational prestige was coded with the Job Zone coding scheme from the Occupational Information Network (O*NET; http://www.onetonline.org/help/online/zones), which ranks U.S. Census-based occupational categories on a scale of 1 to 5 based on the education, experience, and training required. Maternal and paternal occupational prestige levels were averaged, as were maternal and paternal education levels. ITN, parental education, and parental occupational prestige were significantly and positively correlated: ITN and parental education, $r(118) = .50$, $p < .001$; ITN and parental occupational prestige, $r(117) = .54$, $p < .001$; parental education and parental occupational prestige, $r(118) = .69$, $p < .001$. Given these correlations, parent education, parent occupational prestige, and ITN ratio were standardized and averaged to yield a composite SES variable. Correlations of the SES composite with child performance as well as correlations of ITN and parental education with child performance are presented in Table 4.

Analysis plan

To assess possible effects of child age and gender, we tested their associations with each performance measure (working memory and go/no-go accuracies and reaction times) by including them in each repeated-measures model. Whenever there was a main effect of the covariate to the outcome of interest, the covariate was included in subsequent models.

To assess relations of SES to working memory and go/no-go performance, we used repeated-measures analyses of covariance (RM-ANCOVAs) for each task with accuracy as the dependent measure. Trial type was included as a within-participants factor (set size for working memory and go/no-go trial type), and SES was included as a predictor. This allowed us to test for main effects of SES as well as SES × Trial Type interactions. The same analysis was used for working memory reaction time. Statistically, all continuous variables (SES and age) were entered as covariates (Hoffman, 2014; Sweet & Grace-Martin, 2011). We use the term *predictor* for SES to distinguish from age, which we treated as a potential covariate. A Pearson correlation assessed the relation between SES and reaction time on correct go trials of the go/no-go task.

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Table 4
Correlations.

	WM SS1 ACC	WM SS2 ACC	WM SS1 RT	WM SS2 RT	Go trials ACC	No-go trials ACC	Go trials RT
WM SS1 ACC	–						
WM SS2 ACC	$.76^{***}$	–					
WM SS1 RT	$-.41^{***}$	$-.46^{***}$	–				
WM SS2 RT	$-.24^{*}$	$-.31^{**}$	$.86^{***}$	–			
Go trials ACC	$.57^{***}$	$.40^{***}$	$-.36^{***}$	$-.24^{*}$	–		
No-go trials ACC	.09	$.19^{\dagger}$	−.08	.04	.13	–	
Go trials RT	$-.33^{**}$	$-.20^{\dagger}$	$.24^{*}$	$.25^{*}$	$-.37^{***}$	$.54^{***}$	–
SES	$.28^{**}$	.13	$-.24^{*}$	−.15	$.22^{*}$	$.19^{*}$	.11
ITN	.16	.09	$-.18^{\dagger}$	−.13	.13	$.16^{\dagger}$	.10
EDU	$.32^{**}$	$.19^{\dagger}$	$-.24^{*}$	−.13	$.26^{**}$	$.20^{*}$	.09

Note. WM, working memory; SS, set size; ACC, accuracy; RT, reaction time; SES, socioeconomic status; ITN, income-to-needs ratio; EDU, parent education.

† $p < .10$.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

As a follow-up analysis to test for whether performance changed throughout each task, we added block to each RM-ANCOVA as a within-participants factor. This allowed us to test for main effects of block as well as interactions of SES or trial type with block. This approach of first running models with only trial type as a within-participants factor and then running secondary models adding block to the model was done to maximize power given that not all children completed all four blocks of each task.

For all RM-ANCOVAs, post hoc analyses followed up significant main effects using Bonferroni corrections for multiple testing. In RM-ANCOVAs where the assumption of sphericity was violated, we used Huynh–Feldt corrections (epsilon > .75) and Greenhouse–Geisser corrections (epsilon < .75) as necessary (Girden, 1992).

Results

There was a main effect of age in the RM-ANCOVAs for working memory accuracy and working memory reaction time. Age was also correlated with reaction time on correct go trials, $r(115) = -.19$, $p = .04$. Therefore, age was included as a covariate in subsequent models with those dependent variables. There was no main effect of age in the RM-ANCOVA for go/no-go accuracy. Therefore, age was not included in go/no-go accuracy models. There were no effects of gender in any model. See Table 3 for intercorrelations of working memory and go/no-go variables.

Working memory accuracy

In the primary model, we used an RM-ANCOVA with set size (1 or 2) as a within-participants factor, age as a covariate, and SES as a predictor ($N = 95$). There was a main effect of SES, $F(1, 92) = 5.53$, $p = .021$, $\eta_p^2 = .06$, such that lower SES related to worse working memory accuracy. There was also an SES × Set Size interaction, $F(1, 92) = 5.92$, $p = .017$, $\eta_p^2 = .06$. Parameter estimates showed that lower SES related to lower accuracy on set size 1 trials ($B = .04$, $p = .003$), whereas SES was not related to accuracy on set size 2 trials. There was also a main effect of age, $F(1, 92) = 14.75$, $p < .001$, $\eta_p^2 = .14$, such that older age related to higher accuracy.

In the secondary model to test whether accuracy changed throughout the task, block was added to the model ($N = 92$). Therefore, block and set size were included as within-participants factors. SES and age were also included. There was a main effect of block, $F(2.69, 239.70) = 3.10$, $p = .032$, $\eta_p^2 = .03$. Post hoc pairwise comparisons showed that accuracy was significantly lower in Blocks 3 and 4 compared with Blocks 1 and 2 (all *ps* < .01). There were no interactions with block.

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Working memory reaction time

In the primary model, we used an RM-ANCOVA with set size (1 or 2) as a within-participants factor, age as a covariate, and SES as a predictor ($N = 95$). There was a main effect of age, $F(1, 92) = 11.07$, $p = .001$, $\eta_p^2 = .11$, such that older children had quicker reaction times. There was also a main effect of SES, $F(1, 92) = 4.42$, $p = .038$, $\eta_p^2 = .05$, such that lower SES was associated with slower reaction times. There were no interactions.

In the secondary model, to test whether reaction time changed throughout the task, block was added to the model ($N = 92$). There was no main effect of block and no interactions with block.

Go/No-go accuracy

In the primary RM-ANCOVA, trial type (go or no-go) was a within-participants factor and SES was included as a predictor ($N = 117$). There was a main effect of trial type, $F(1, 115) = 191.61$, $p < .001$, $\eta_p^2 = .63$, such that children were more accurate on go trials compared with no-go trials. There was also a main effect of SES, $F(1, 115) = 7.35$, $p = .008$, $\eta_p^2 = .06$, such that lower SES related to lower accuracy. There was no SES × Trial Type interaction.

In the secondary model, block was added ($N = 105$). There was a main effect of block, $F(2.70, 278.41) = 11.91$, $p < .001$, $\eta_p^2 = .10$. Post hoc pairwise comparisons showed that accuracy was higher in Block 1 compared with Blocks 2, 3, and 4 (all $ps < .01$).

There was also a Block × Trial Type interaction, $F(2.91, 299.20) = 15.23$, $p < .001$, $\eta_p^2 = .13$ (see Fig. 3). Follow-up RM-ANCOVAs were run separately for go and no-go trial types with block as a within-participants factor. In the RM-ANCOVA for go trials, there was no main effect of block. Thus, performance on go trials did not change over the course of the task. Conversely, there was a main effect of block in the RM-ANCOVA for no-go trials, $F(2.76, 283.79) = 16.73$, $p < .001$, $\eta_p^2 = .14$. Post hoc pairwise comparisons showed that performance was highest in Block 1 compared with all other blocks (all $ps < .001$) and was higher in Block 2 compared with Block 4 ($p = .028$). In sum, children maintained accuracy throughout the task on go trials, indexing general vigilance, but their accuracy on no-go trials, indexing inhibitory control, declined throughout the task. There were no interactions with SES.

Go trials reaction time

Age was significantly related to reaction time on correct go trials, $r(115) = -.19$, $p = .04$. To assess the relation between reaction time on correct go trials and SES, controlling for age, a partial correlation was used. There was no relation between SES and reaction time on correct go trials.

To assess for changes in go reaction time across the task, an RM-ANCOVA was run with block as a within-participants factor and SES and age included as covariates. There was a nonsignificant trend of a main effect of block, $F(3, 306) = 2.57$, $p = .055$, $\eta_p^2 = .03$, such that reaction time became quicker throughout the course of the task.

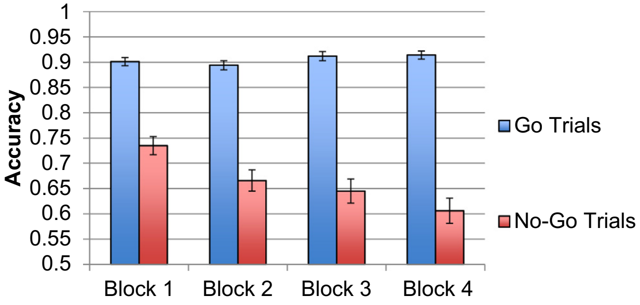

Fig. 3. Overall, children's accuracy on go trials, indexing general vigilance, remained consistent throughout the four blocks of the task. In contrast, accuracy on no-go trials, indexing inhibitory control, declined throughout the task.

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Discussion

We examined how SES relates to multiple aspects of EF processing in early childhood using a systematic and nuanced approach. Children aged 4.5–5.5 years completed working memory and go/no-go tasks. We examined the role of SES for both accuracy and reaction time as well as whether SES–EF relations varied by cognitive load, by go/no-go trial type, or in the capacity to maintain performance across the duration of the task. Overall, there were SES differences in children's accuracy on both tasks and working memory reaction time but not on reaction time on the go/no-go task. Lower-SES children had lower accuracy when remembering one item in working memory, but there were no SES differences when children needed to remember two items. All children's accuracy declined over the duration of the tasks regardless of SES. Results demonstrate that overall SES is linked to poorer EF for most domains in this age range. However, it is notable that those limited aspects of EF that did *not* show an SES difference were EF abilities that are currently emerging at this developmental stage for all children, including the ability to maintain performance over an extended period of time and to remember items at a higher cognitive load.

To our knowledge, this is the first study to consider children's working memory capacity within the context of SES. We build on past research demonstrating a link between SES and composite accuracy measures of working memory in children (Farah et al., 2006; Hackman et al., 2015; Noble et al., 2005, 2007) and show that SES relates to the cognitive load aspect of working memory, controlling for child age. Specifically, in this age group of 4.5–5.5 years, when children needed to remember one item, lower-SES children had poorer accuracy. However, SES was not related to working memory accuracy when children needed to remember two items. This finding is contrary to our expectations; we hypothesized that stronger SES differences would be seen for higher cognitive load trials. Given that working memory capacity increases with development (for reviews, see Cowan, 2016, and Kibbe, 2015; Riggs et al., 2006; Simmering, 2012), our results suggest that in this age range of 4.5–5.5 years SES may relate to cognitive skills that are earlier developing and more well established (e.g., remembering only a single item in working memory), whereas skills that are later developing (e.g. remembering multiple items in working memory) might not yet be related to SES.

It is possible that SES differences in working memory capacity would continue to grow with time. Past longitudinal research assessing working memory in early and middle childhood found that SES disparities remained consistent over time (Hackman et al., 2014, 2015). However, this study included one working memory variable that did not differentiate by cognitive load and also included tasks that made significant verbal demands. Furthermore, the relation between SES and working memory capacity may look different in other age groups. The pattern could be similar to that of our study such that SES differences are more pronounced in lower set sizes. For example, in older children SES differences may be greater at set size 3, whereas all children may find set size 4 challenging. Alternatively, it is possible that the pattern shifts and SES differences become more pronounced at higher set sizes as children get older. Future longitudinal research is needed for understanding how SES differences in working memory capacity may change over time.

Lower SES was linked to lower accuracy in the go/no-go task on both no-go and go trials, demonstrating that lower SES related to poorer inhibitory control and general vigilance. To our knowledge, this is the first study to assess how SES relates to both aspects of the go/no-go task as separate and distinct outcomes. This finding builds on past SES research in which no-go trial accuracy was included in a composite measure of EF (Noble et al., 2005, 2007). Thus, our results suggest that lower-SES children are struggling with both aspects of this task and not one or the other. Because SES is also affecting children's vigilance, as indexed by lower accuracy on go trials, this provides additional information on potential targets for intervention and prevention to improve child EF.

In addition to overall performance, we examined how children's accuracy changed over the course of the tasks and whether accuracy changed as a function of SES. Past studies have typically not assessed children's ability to maintain EF performance across time. This is a crucial aspect of EF to assess, especially in the context of SES. SES differences in composite measures could reflect a deficit in the specific EF skill assessed or could be due to a loss of focus and, thus, a quicker decline in performance. Assessing children's performance on the specific EF skill (e.g., working memory, inhibitory

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control) as well as change in their performance throughout a task can help to clarify the source of SES differences in a composite measure. In our study, children's accuracy declined in both the working memory and go/no-go tasks such that accuracy in the beginning was higher than at the end. However, contrary to our expectations, the decline in accuracy did not vary as a function of SES. Thus, overall children struggled to maintain performance. Because SES did relate to children's overall accuracy in the tasks, but not to their maintenance of performance over time, this helps to rule out the possibility that SES differences were attributable to difficulty in staying on task. Rather, results suggest that SES differences in EF measures are indeed due to differences in EF and not the maintenance of performance.

The decline in performance during the course of the working memory task was consistent across cognitive load; however, there were differences in maintenance of performance in the go/no-go task. Specifically, there was no change in general vigilance accuracy over time (go trials); however, children's inhibitory control accuracy did decline over the course of the task. Again, these patterns did not vary as a function of SES. Given the way in which the go/no-go task is designed, this is not entirely surprising. The majority of trials in this task are go trials where children are told to press the button. Therefore, children's prepotent response is to press the button. Conversely, the no-go trials inherently require more cognitive demands because children must recognize the target animal and also inhibit their dominant response to press the button. Thus, it follows that it is harder for children to maintain their accuracy throughout the course of the task on the more difficult trials.

In addition to overall SES differences in EF accuracy, one might also expect that lower-SES children might have more trouble in maintaining interest in or attention to the task, which could result in a more extreme drop in performance over the course of the task relative to their higher-SES peers. However, that pattern was not observed in our data. Rather, whereas for the most part lower SES was linked to poorer EF performance, all children similarly struggled with staying on task regardless of SES. This could be because maintaining interest and consistent attention throughout a cognitively demanding task is a newly emerging skill. All children in this preschool age range, regardless of their SES background, are still working on the ability to remain on task. These results are in a way comparable to the working memory finding. Specifically, there were no SES differences in working memory when cognitive load was higher. Thus, although overall the general pattern of results showed that SES was linked to poorer EF, SES differences were not observed in the aspects of EF that are still emerging for this developmental stage. Further research is needed to assess whether these findings remain stable or change with development. It is possible that as children grow older and these aspects of EF become more established, SES differences could widen in the ability to maintain performance and/or in working memory at high cognitive load.

SES also related to overall reaction time on the working memory task. Thus, lower-SES children were responding more slowly and with lower accuracy. However, there was no change in children's reaction time throughout the course of the working memory task. It is unclear what the underlying mechanisms are explaining these differential relations. It is possible that children are processing the stimuli in different ways. Recent research has used event-related potentials (ERPs) to better understand children's neural processing during EF tasks (Buss, Dennis, Brooker, & Sippel, 2011; Espinet, Anderson, & Zelazo, 2012; Grammer, Carrasco, Gehring, & Morrison, 2014; Willner, Gatzke-Kopp, Bierman, Greenberg, & Segalowitz, 2015). In particular, ERPs have been used to help tease apart SES differences in processing even in the absence of behavioral differences in performance (D'Angiulli, Herdman, Stapells, & Hertzman, 2008; Stevens, Lauinger, & Neville, 2009). Future research examining how SES relates to children's ERPs assessed in EF tasks could help to elucidate the underlying neural mechanisms that could explain the link between SES and behavioral EF performance.

SES did not relate to reaction time on go trials. However, overall there was a trend such that children became quicker on go trials throughout the course of the task. This finding is relevant given that children's accuracy on no-go trials declined throughout the task. Together, these results suggest that there may indeed be trade-offs in processing speed and EF performance (Best et al., 2011; Davidson et al., 2006). Thus, as children became quicker at responding to the go trials, which occurred more often than the no-go trials, this may have contributed to more errors on the no-go trials throughout the course of the task. These results indicate that processing speed may be intertwined with EF performance and underscore the importance of considering both reaction time and accuracy to better understand the mechanisms underlying EF processes. Furthermore, because EF predicts academic success (Bull, Espy, & Wiebe, 2008), more research is needed to further examine speed–accuracy tradeoffs within the context of SES and within this age group. Future directions could include experimentally manipulating a task by varying the instructions given (e.g., "play as fast as possible" vs. "play slowly and carefully") as well as by assessing both performance measures in tasks tapping cognitive flexibility.

Overall, these findings have practical implications. Past research has linked SES to EF assessed with composite measures (Farah et al., 2006; Noble et al., 2007; Raver et al., 2013), implying that lower SES is linked to a global deficit in EF. Our results for the most part are consistent with this given that lower SES related to poorer EF functioning in most domains. However, we provide further specificity and demonstrate that lower-SES children had poorer accuracy when holding one item in working memory, had lower inhibitory control and vigilance, and had slower working memory reaction time. Conversely, there were no SES differences for working memory accuracy at a higher cognitive load, and there were no SES differences in maintenance of performance over time. This may have potential practical implications by providing information on more specific targets for intervention. For example, interventions could focus on the acquisition of basic working memory processes as well as inhibitory control and vigilance, with potential implications for improving child academic outcomes. However, a first step would be to use experimental designs to establish causal links between targeting these areas and improving school success. These findings also add to the literature on relations between SES and child outcomes, which overall may help to encourage interventions and policy changes. Specifically, because SES differences were especially evident for skills that should be more established, results suggest that intervention and policy efforts should focus on providing support early in life at the developmental stage when EF skills are just developing and before SES differences become entrenched.

We designed this study as a nuanced assessment of relations between SES and EF. However, children develop within a dynamic bioecological context (Bronfenbrenner & Morris, 1998; Ursache & Noble, 2016). Thus, the current results do not provide information on the roles of familial and environmental factors such as parenting and household chaos, which have been shown to matter for child EF (Bernier, Carlson, & Whipple, 2010; Blair et al., 2011; Deater-Deckard, Chen, Wang, & Bell, 2012; Hackman & Farah, 2009; Vernon-Feagans, Willoughby, & Garrett-Peters, 2016). An important step forward would be to merge these approaches to understand how environmental factors at multiple levels may relate to children's working memory capacity as well as to children's ability to maintain EF performance over time.

An additional limitation is that we did not include a comprehensive battery of EF measures. Additional key aspects of EF that are important include cognitive flexibility/set shifting, sustained attention, and attention shifting. We determined from piloting that to validly assess our constructs of interest, it was necessary to limit the length of the visit given the constrained amount of time that younger children can pay attention and the taxing nature of these tasks. Future research would be strengthened by including additional EF measures, which could be accomplished through repeated laboratory visits or by examining these questions in an older age range.

Given the length of the tasks, we used motivational techniques, including stories and stickers, to encourage children to complete the tasks. Researchers often distinguish between "cool" and "hot" EF tasks. Cool tasks are purely cognitive, whereas hot tasks involve an emotional component, such as a reward, at stake (Zelazo & Carlson, 2012). Although our tasks did involve motivation, they are likely not classified as hot tasks because children's earning of stickers did not depend on their performance. In the introduction to the tasks, children were told that they would earn stickers by playing the games. They were not told that they would earn stickers depending on how *well* they played the game. Thus, regardless of performance, all children received two stickers after each block.

Moreover, an inherent limitation of research conducted in a laboratory setting is that there could be a bias regarding which families come in to participate. Participating in research requires a time commitment, travel, and motivation. Thus, it is possible that the families that participate are different from those that do not. Finally, higher-SES children were more likely to perform above chance on the working memory task compared with lower-SES children and, thus, were more likely to be included in analyses. However, our criterion of including only children who performed above chance helped to

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ensure that only children who understood the task were included. Thus, it should be noted that even when including only children who understood the task, we still saw SES differences.

This study assessed the scope of how SES relates to a multidimensional assessment of EF in children. Lower SES related to working memory accuracy at a lower cognitive load, to overall working memory reaction time, and to both inhibitory control and general vigilance accuracy. SES did not relate to working memory at a higher cognitive load and did not relate to children's maintenance of performance during the tasks. Furthermore, SES did not relate to children's reaction time on the go/no-go task. These results demonstrate that SES was linked to differences in children's EF in most domains. However, findings also suggest a developmental pattern of the emergence of working memory and maintenance of performance, with implications for intervening early before SES-linked differences are entrenched.

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