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Neighbourhood chaos moderates the association of socioeconomic status and child executive functioning

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Abstract

Although broad associations between socioeconomic status (SES) and child executive functions (EFs) are well established, contextual factors that may matter for effects of SES on EF are not fully understood. This study used a bioecological approach to examine factors that may moderate SES–EF relations. A socioeconomically diverse sample of children ages 4.5–5.5 completed working memory and go/no-go tasks. Parents reported on well-being, household chaos, and neighbourhood chaos. Higher SES related to better working memory performance and higher accuracy on go trials, but neighbourhood chaos moderated these associations. Specifically, for higher neighbourhood chaos, the relations between SES and working memory and go accuracy (indexing general vigilance) were especially pronounced, such that the best EF performance was observed in children in high-SES households who experienced higher neighbourhood chaos. Results highlight the relevance of neighbourhood quality for underlying processes of EF development, particularly in the context of high SES. Further, findings suggest the importance of teasing apart specific contextual factors that matter for child cognitive functioning.

Highlights

- Children ages 4.5-5.5 years completed working memory and go/no-go tasks to assess executive function. Parents reported on household socioeconomic status, well-being, household chaos and neighborhood chaos.

- In more chaotic neighbourhoods, SES was significantly related to child executive functions such that children with both high-SES and high-neighbourhood chaos showed better executive function performance.
- Results highlight the importance of considering the interplay of contextual factors and socio-economic status in early childhood executive function development.

KEYWORDS

early childhood, executive function, neighbourhood chaos, neighbourhood quality, socioeconomic status, working memory

1 | INTRODUCTION

Executive function (EF) involves higher order cognitive and goal-directed processes (Anderson, 2002; Best & Miller, 2010; Diamond, 2013). The development of EF in early childhood is critical as it provides a foundation for later academic achievement (Bull, Espy, & Wiebe, 2008; Fuhs, Nesbitt, Farran, & Dong, 2014; Morgan, Farkas, Hillemeier, Pun, & Maczuga, 2018; Schmitt, Geldhof, Purpura, Duncan, & McClelland, 2017), as well as socioemotional functioning (de Wilde, Koot, & van Lier, 2015; Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006). However, lower socioeconomic status (SES) has been consistently linked to poorer EF in children (Farah et al., 2006; Lawson, Hook, & Farah, 2017; Noble, Norman, & Farah, 2005; Raver, Blair, & Willoughby, 2013).

SES is a multidimensional construct that reflects financial resources and capital (Bradley & Corwyn, 2002). Household income, parental education, and parental occupation are typically used as indicators of SES (Hackman & Farah, 2009; Ursache & Noble, 2016). In addition to negatively impacting child EF, lower SES predicts adverse outcomes including worse psychological well-being, poorer health, and lower scores on measures of academic achievement (see for review, Bradley & Corwyn, 2002; Hackman, Farah, & Meaney, 2010). However, although low SES can co-occur with many other risks (Bradley & Corwyn, 2002; Evans, 2004; Hackman & Farah, 2009), broad indices of SES do not necessarily capture the child's day-to-day environment. It is possible that different aspects of a child's immediate context could change the nature of how SES relates to EF.

1.1 | Interaction of socioeconomic status and sociocontextual factors

Bronfenbrenner's bioecological model takes a holistic view and argues that development occurs as a result of the interaction between individuals and their environments (Bronfenbrenner & Morris, 2007). The model emphasizes the roles of multiple levels of the environment for development. Further, the model stipulates the significance of experience for development, including both the way that a person subjectively experiences their environment as well as objective environmental factors (Bronfenbrenner & Morris, 2007). Therefore, when assessing how SES may matter for child EF, subjective experiences of sociocontextual factors merit consideration.

Children of similar SES may have differing environments at familial and neighbourhood levels, which could affect their experience of SES and ultimately their EF. To better understand the complex processes through which SES relates to child EF, a bioecological framework is needed to assess how contextual factors at multiple levels of the child's environment may moderate the effects of SES (Bradley & Corwyn, 2002). For instance, a child could grow up in a low SES environment but have a parent with high well-being. In this case, high parental well-being could promote EF development and offset any negative effects of low SES. Thus, consistent with theoretical propositions (Greenberg, 2006; Masten & Monn, 1995), high parental well-being may protect the child from the adverse consequences of low SES. In sum, it is possible that low SES in conjunction with additional risks (e.g., low quality home environment) could more strongly relate to child EF.

Assessing variation in the experience of SES is critical to expanding our understanding of the implications of SES for child EF. For instance, teasing apart these complex interactions and processes between SES and specific contextual factors in the child's environment could help inform intervention efforts to pinpoint which children are most at risk. When addressing this question, a consideration of multiple levels of the child's environment from more proximal (e.g., parents and household) to more distal environments is needed (e.g., neighbourhood; Bronfenbrenner & Morris, 2007), given that children develop within many contexts. Three environmental factors that are likely candidates for moderating the role of SES include parental well-being, household chaos, and neighbourhood chaos. These factors often, but not always, are related to SES. Further, there would likely be variability of these factors within both high and low SES families. Thus, there could be low-SES families with high parental well-being as well as high-SES families with low parental well-being. Given this expected variability, these factors could be sensitive to potential moderation effects and are a starting point in examining how factors at varying levels of the environment may interact with SES.

1.2 | Parental well-being

A key proximal factor that matters for child EF is parental well-being. Parents play a vital role for the development of EF (Bernier, Carlson, & Whipple, 2010; Blair et al., 2011; Cuevas et al., 2014; Huhtala et al., 2014). Higher parental well-being, as indexed by lower levels of parent depression (Gueron-Sela, Camerota, Willoughby, Vernon-Feagans, & Cox, 2018; Hughes, Roman, Hart, & Ensor, 2013; Huhtala et al., 2014) and lower amounts of parenting stress, has been associated with better child EF (Huhtala et al., 2014). Furthermore, parents can promote child cognitive development through interactions such as scaffolding in problem-solving situations (Bernier et al., 2010; Hammond, Müller, Carpendale, Bibok, & Liebermann-Finestone, 2012; Matte-Gagné, Bernier, & Lalonde, 2014). Lower SES parents are more likely to experience psychosocial stressors and challenges, which may affect their well-being and ultimately their ability to provide sensitive caregiving (see for review, Blair & Raver, 2016). For instance, higher economic hardship, such as unstable work, contributes to lower parental psychological well-being (Newland, Crnic, Cox, & Mills-Koonce, 2013).

Given the implications of parental well-being for child EF, it is likely a meaningful indicator of a child's day-to-day experience that may interact with SES. Low SES and poor parental well-being have both been associated with worse child EF (Gueron-Sela et al., 2018; Huhtala et al., 2014; Lawson et al., 2017). Therefore, one could speculate that if a child from a low socioeconomic background also has a parent with poor well-being, then these risk factors may combine to especially impact this child's EF. Conversely, other parents may maintain high levels of well-being and could promote their child's EF development. In this case, SES may not have as strong a relation to EF in the context of high parental well-being. However, these potential interactions have not yet been examined.

1.3 | Household chaos

An additional factor that may interact with SES is the household environment, specifically household chaos. High household chaos is characterized as greater levels of confusion, noise, and activity and a lack of structure (Dumas et al., 2005; Evans, Gonnella, Marcynyszyn, Gentile, & Salpekar, 2005; Wachs & Evans, 2010). Higher household chaos has been related to poorer child behaviour regulation (Evans et al., 2005; Martin, Razza, & Brooks-Gunn, 2012; Vernon-Feagans, Willoughby, & Garrett-Peters, 2016) and receptive language (Martin et al., 2012). It is possible that more chaotic homes are over stimulating for children. Thus, children growing up with more chaos, such as noise and lack of structure may not be able to take advantage of stimulating opportunities such as parental scaffolding (Vernon-Feagans et al., 2016). Therefore, in more unstable and chaotic homes, children may be more vulnerable to the effects of low SES.

1.4 | Neighbourhood chaos

In addition to parental and household factors, an additional level of the environment to consider is the neighbour -hood. Disadvantaged neighbourhoods are linked to worse physical and mental health (Diez Roux & Mair, 2010), child verbal ability (Sampson, Sharkey, & Raudenbush, 2008), educational attainment (Boyle, Georgiades, Racine, & Mustard, 2007), cortisol functioning (Finegood, Rarick, Blair, & Investigators, 2017; Karb, Elliott, Dowd, & Morenoff, 2012; Theall, Shirtcliff, Dismukes, Wallace, & Drury, 2017), and adult cognitive functioning (Shih et al., 2011; Wight et al., 2006). Furthermore, given the relevance of assessing the experience of SES, it is important to consider families' perceptions of where they live. For example, studies have demonstrated that parents' views on the quality of the physical neighbourhood and feelings of safeness have implications for children's moral development (Ball, Smetana, Sturge-Apple, Suor, & Skibo, 2017) and behavioural problems (Ma & Grogan-Kaylor, 2017). Low neighbourhood quality may be linked to cognitive development through proximal processes such as access to resources, parenting, and parental well-being (see for review, Minh, Muhajarine, Janus, Brownell, & Guhn, 2017). Furthermore, perceptions of the neighbourhood have been shown to moderate the association between family risk and child externalizing behaviours (Lima, Caughy, Nettles, & O'Campo, 2010). Specifically, there was a strong relation between family risk and child externalizing behaviours when parents perceived a negative social climate in their neighbourhood (Lima et al., 2010).

Although, to our knowledge, the role of parental perception of the neighbourhood environment for child EF has not yet been studied, researchers have examined objective measures of neighbourhood quality. For instance, moving from a high to low poverty neighbourhood was associated with increases in child self-regulation (Roy, McCoy, & Raver, 2014). However a longitudinal study found no relation in 10–13 year olds between working memory and neighbourhood SES, assessed using various census data (e.g., percentage of unemployed individuals and percentage of individuals below the poverty line; Hackman et al., 2014). However, it is unclear how the neighbourhood environment may moderate effects of SES.

1.5 | Current study

Children are embedded in their environments and daily experiences may vary among children of similar SES. Therefore, it is important to investigate specific factors that may alter how SES relates to child EF. Building on the bioecological model of human development, the goal of the current study was to examine how multiple levels of the environment, including parental, household, and neighbourhood factors, interact with SES in relation to child EF. We measured EF in 4.5- to 5.5-year-old children, given the significance of this period for school readiness (e.g., Morgan et al., 2018). Further, given that EF by these ages is multidimensional (Monette, Bigras, & Lafrenière, 2015; Simanowski & Krajewski, 2017), we assessed multiple aspects of EF including sustaining attention, inhibitory control, and working memory, which in this paper is defined as holding information in mind (Luck & Vogel, 1997; Riggs, McTaggart, Simpson, & Freeman, 2006; Simmering, 2012). Parental depression and parenting stress were assessed as measures of parental well-being. To index household and neighbourhood quality, parents reported on household chaos and neighbourhood chaos. We expected that SES would relate to child EF. We also expected that parental well-being, household chaos, and neighbourhood chaos would moderate the relation of SES and child EF such the association of SES and EF would be attenuated in the context of higher parental well-being, less chaotic households, and higher quality neighbourhoods.

2 | METHODS

2.1 | Participants

Participants were 121 children (70 females) aged 4.5 to 5.5 years and their participating parents (108 mothers). 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 as well as race/ethnicity data). An

TABLE 1 Demographics

Variable Name	M (SD)
Maternal age (years)	36.20 (5.30)
Paternal age (years)	39.32 (7.19)
Child age (years)	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	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)	3.28 (1.26)
Paternal occupational prestige (1–5 scale)	3.50 (1.07)

additional four children enrolled in the study but were not included in analyses due to declining to participate in both of the tasks (*N* = 3) and not understanding both tasks (*N* = 1).

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 they had an income less than three times the federal poverty line, given their household size. Given the high cost of living and childcare in the urban setting where this study was conducted, one analysis concludes that an income of $73, 776 is needed to meet basic needs (Ames, Lowe, Dowd, Liberman, & Youngblood, 2013). The federal poverty line for a family of four is $24, 600, regardless of regional differences in cost of living, and a household who makes 3 times this amount would total to $73, 800. Thus, a family who makes less than 3 times the federal poverty line in this sample is considered financially strained. The median ITN of the sample was 3.39. For further breakdown of the income and education distribution of the sample, see Table 2.

2.2 | 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 Starts, diaper banks, community play groups, and a community health centre. This study was approved by the university Institutional Review Board. Parent–child dyads visited the laboratory for one session lasting 1.5 to 2.0 hr. 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, they 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 child completed receptive language and nonverbal IQ measures and parents completed questionnaires.

2.3 | Measures

2.3.1 | Working memory

Children completed an adapted version of a change detection task (Luck & Vogel, 1997; Riggs, McTaggart, et al., 2006; Simmering, 2012). For each trial, children saw either one or two 1-inch coloured squares (1,000 ms). Colours

TABLE 2 Income-to-needs (ITN) and parent education information

ITN grouping	Frequency	Percentage	Cumulative percentage
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%

Abbreviation: ITN, income-to-needs.

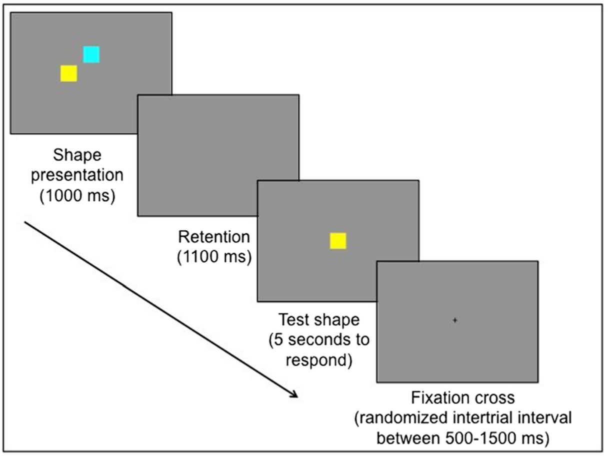

FIGURE 1 Visual depiction of the working memory task

were randomized, and same colours were not repeated within each presentation. Children then saw a blank screen (1,100 ms). Finally, one colour was presented in the middle of the screen (test) and children had 5 sec to respond as to whether they saw the colour before (see Figure 1). Children responded "yes" or "no" with a response pad that had two buttons: a green "thumbs up" for "yes" and a red "thumbs down" for "no." Following the test shape presentation, a fixation cross was presented for a randomized inter-trial interval ranging from 500 to 1500 ms. 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).

This adapted change detection task assesses working memory, defined as holding information in mind (Riggs, McTaggart, et al., 2006; Simmering, 2012). This task also reflects the definition of working memory as the updating of information (see for review, Friedman & Miyake, 2017), as children are updating information in mind to assess whether they saw the colour before. There is an alternate definition such that working memory has been defined as holding information in mind while also manipulating it (Best & Miller, 2010; Diamond, 2013). The change detection task used in the current study does not apply to this definition.

The experimenter first practiced the game with the child with laminated cards to ensure that they understood the task, per 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 (one or two), 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 colours, 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 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.

Overall accuracy, the proportion of correct responses, was computed (possible range from 0.00–1.00, $M = .77$, $SD = .12$). To ensure that only children who understood the task were included in working memory analyses, children had to perform above chance on overall accuracy (≥.57, binomial $p < .05$); 95 (78.51%) children 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, $t\ (118) = -2.31$, $p = .023$. There was not a difference in age when comparing the children who performed above and below chance, $t\ (119) = -1.83$, $p = .07$. The entire task took around 20 min to complete. For further details on administration of this task with this sample, see [blind citation]. See Table 3 for descriptive statistics of study measures.

2.3.2 | 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 Figure 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). Children had 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 inter-trial 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 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). The no-go trials index inhibitory control, as children have 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).

TABLE 3 Descriptive statistics of study variables

Measure	M (SD)	Min	Max	N
Working memory accuracy	.77 (.11)	.57	.99	95
Accuracy in go trials	.90 (.07)	.65	1.00	117
Accuracy in no-go trials	.64 (.20)	.11	.99	117
Language	105.51 (13.87)	76.94	145.00	117
Nonverbal IQ	100.86 (11.99)	68.00	141.00	118
Parental depression (possible range 0–60)	8.72 (6.16)	0.00	36.00	119
Parenting stress (possible range 1–5)	2.17 (.37)	1.33	3.28	100
Household chaos (possible range 1–5)	2.12 (.68)	1.00	3.50	119
Neighbourhood chaos reverse scored (possible range 1–4)	2.36 (.47)	1.07	3.00	120
Components of objective neighbourhood measure				
Adults >25 years old with less than a high school education (%)	11.59 (10.00)	0.00	61.40	117
Unemployed males (%)	8.84 (8.86)	0.00	82.10	117
Households with an income below the poverty line (%)	12.48 (11.57)	0.00	40.10	117
Receiving public assistance (%)	3.60 (3.56)	0.00	23.30	117
Households with children that are headed by a female (%)	14.10 (11.06)	0.00	58.80	117
Median household income ($)	70,535.66 (35,075.45)	21,635.00	180,588.00	117

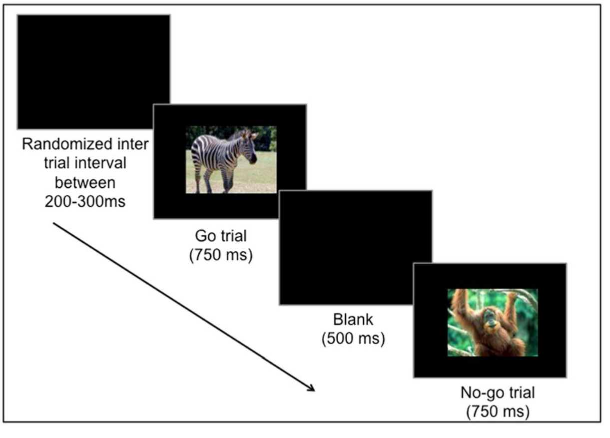

FIGURE 2 Visual depiction of the go/no-go task

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 their go accuracy. Three children met these criteria and were excluded from go/no-go analyses. An additional child declined to complete the task. This left a final sample of 117 children for go/no-go analyses. The task took around 12 minutes to complete.

2.3.3 | Language

Children completed the picture vocabulary test (normed for ages 3–85) from the National Institutes of Health Toolbox Cognition Battery (Gershon et al., 2014). This measures receptive vocabulary and uses a computerized adaptive format based on performance. The child hears a word and sees four photographs on the screen and is asked to select the picture that most closely matches the meaning of the word. Age-adjusted scores were used. Four children did not have scores due to technical difficulties.

2.3.4 | Nonverbal IQ

The matrices sub-scale of the Kaufman Brief Intelligence Test was used. The assessment is multiple choice and involves the child pointing to pictures that reflect an understanding of both meaningful and abstract relationships. The task takes 5 to 10 min to complete. Age-adjusted scores were used. This assessment was not administered to three children.

2.3.5 | 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 1–5 scale based on the education, experience, and training required. Maternal and paternal occupational prestige was averaged as were maternal and paternal education. 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, $p < .001$; and parental education and parental occupational prestige, r (118) = .69, $p < .001$. Given these correlations, parent education, parent occupational prestige, and ITN were standardized and averaged to yield a composite SES variable.

2.3.6 | Parental well-being

Depression

The Center for Epidemiologic Studies-Depression Scale (CES-D; Radloff, 1997), a 20-item questionnaire, was used. The CES-D has internal, concurrent, and predictive validity (Bureau, Easterbrooks, & Lyons-Ruth, 2009). The range is 0 to 60, with a clinical cutoff of 16 (Cronbach's $\alpha = .79$) and higher scores indicating higher levels. Sixteen parents (13.22%) scored above the clinical cutoff and thus met criteria for depression.

Parenting stress

We used the Parenting Stress Index, 4th Edition short form (Abidin, 1995). Parents rated 36 items on a 5-point scale, which were averaged to yield a Total Stress Scale (Cronbach's $\alpha = .89$), with higher scores indicating more parenting stress. Seven questions were part of the Defensive Responding scale to assess if parents were answering to look favourable by minimizing problems or negativity. Parents with a score of less than 10 on this scale are considered defensive responders. Thirteen parents met this criterion and their scores were not included in analyses. The PSI is validated for use with parents of children aged 1 month to 12 years (Abidin, 1995).

Depression and parenting stress were significantly correlated, r (98) = .37, $p < .001$. In addition, these variables are also conceptually related as they both reflect parental perceptions of their mental state, and high levels of parenting stress or depression could be expected to interfere with parenting. Given the statistical and conceptual relations of parenting stress and depression, they were standardized and averaged into a composite of parental well-being. This measure was reverse-scored; therefore, higher scores indicate higher levels of parenting well-being.

2.3.7 | Household chaos

Parents completed the short version of the Confusion, Hubbub, and Order Scale (CHAOS; Matheny et al., 1995). This six-item parent report assesses the level of chaos in the home environment (Cronbach's $\alpha = .63$). Sample items include, “You can't hear yourself think in our home” and “It's a real zoo in our home.”

2.3.8 | Neighbourhood chaos

Parents rated their perceptions on the quality of their neighbourhood on 26 items of the Neighbourhood Organization and Affiliation Scale-Revised (NOAA; Knight, Smith, Martin, Lewis,, & the LOGSCAN Investigators, 2008). The neighbourhood chaos subscale was used, which was comprised of 14 items in which parents report on problems in the neighbourhood such as vandalism, feeling safe, and drug activity (Cronbach's $\alpha = .92$). Sample items include: “In my neighborhood, I always feel safe” and “In my neighborhood, there is open drug activity.” This measure was reverse scored so higher scores reflect higher neighbourhood quality.

2.4 | Analysis plan

Using Pearson correlations, we assessed how SES, parental well-being, household chaos, and neighbourhood chaos related to child EF measures (working memory accuracy, go accuracy, and no-go accuracy). Next, we examined whether the relations of SES and the child EF measures differed as a function of parental well-being, household chaos, and neighbourhood chaos. Therefore, each variable was tested as a potential moderator in separate models for each EF measure, controlling for child age, language ability, and nonverbal IQ. In each of these models, the EF measure was the dependent variable and SES was the independent variable. Moderation analyses were conducted using the PROCESS macro in SPSS (Hayes, 2013) with significant effects estimated using bias-corrected bootstrap confidence intervals at the 95% level and based on 5,000 samples. In regards to missing data, a participant had to have all relevant variables to be included in a given model. Thus, the sample sizes varied across different moderation models.

3 | RESULTS

Pearson correlations showed that higher SES related to higher working memory accuracy, $r\ (93) = .22$, $p = .03$, go accuracy $r\ (115) = .22$, $p = .015$, and no-go accuracy, $r\ (115) = .19$, $p = .037$. In addition, higher parental well-being was associated with better working memory, r (91) = .26, $p = .014$. See Table 4 for correlations of SES and environmental factors with EF.

Ordinary least squares path analysis (Hayes, 2013) was conducted to determine whether parental well-being, household chaos, and neighbourhood chaos moderated the association between SES and child working memory. Child age, language, nonverbal IQ, and parent gender were included as covariates. As shown in Figure 3 and Table 5, a conditional process model, $F\ (7, 81) = 5.24$, $p < .001$, yielded a significant SES × Neighbourhood Chaos interaction ($B = -.07$, $p = .046$, CI:. -0.13 – –0.0012; $\beta = -.20$, CI: –0.40 - -0.004), revealing a conditional effect of SES on child working memory. Assessing the SES × Neighbourhood Chaos interaction, Figure 3 shows that for higher levels of reported neighbourhood chaos, SES is positively associated with working memory. The entire model accounted for 31.18% of the variance in child working memory. The interaction explained 3.45% of the variance in child working memory. Parental well-being ($B = .01$, $p = .69$, $\beta = .04$) and household chaos ($B = -.01$, $p = .45$, $\beta = -.08$) did not moderate the relation of SES and child working memory.

Parallel analyses were conducted for SES and child go accuracy (indexing sustained attention). Child age, language, nonverbal IQ, and parent gender were included as covariates. As shown in Figure 4 and Table 6, a conditional process model, $F\ (7, 102) = 4.23$, $p < .001$, yielded a significant SES × Neighbourhood Chaos interaction ($B = -.04$, $p = .03$, CI: –0.07 – –0.003; $\beta = -.20$, CI: –0.38 - -0.02), showing a conditional effect of SES on child go accuracy. Comparable with the working memory moderation model, SES was positively associated with go accuracy in neighbourhoods where parents reported high levels of chaos (Figure 4). The entire model explained 22.51% of the variance in go accuracy. The interaction explained 3.59% of the variance in child go-accuracy. Parental well-being ($B = -.00$, $p = .83$, $\beta = .02$) and household chaos ($B = .00$, $p = .76$, $\beta = .03$) did not moderate the association of SES

TABLE 4 Correlations

Measure	SES	Parent well-being	Household chaos	Neigh chaos	Objective Neigh	WM	Go	No-go	Language	Nonverbal IQ	Child age	Parent gender
SES	-											
Parental well-being	.19*	-										
Household chaos	–.20*	–.26**	-									
Neigh chaos	.35*	.14	–.27**	-								
Objective neigh	.62***	.12	–.20*	.57***	-							
WM	.22*	.26*	–.12	–.04	.06	-						
Go	.22*	.04	.02	.14	.17†	.53***	-					
No-go	.19*	.03	–.08	.17	.11	.15	.13	-				
Language	.41***	.08	–.08	.11	.33***	.20†	.13	.04	-			
Nonverbal IQ	.16†	–.03	–.14	.01	.18	.26*	.03	.22*	.35***	-		
Child age	.11	–.01	–.08	.10	–.00	.36***	.34***	.03	–.06	–.04	-	
Parent gender	–.04	.14	.02	.00	–.00	.02	–.09	.00	.10	–.25**	.05	-

†$p < .10$,
*$p < .05$,
**$p < .01$,
***$p < .001$

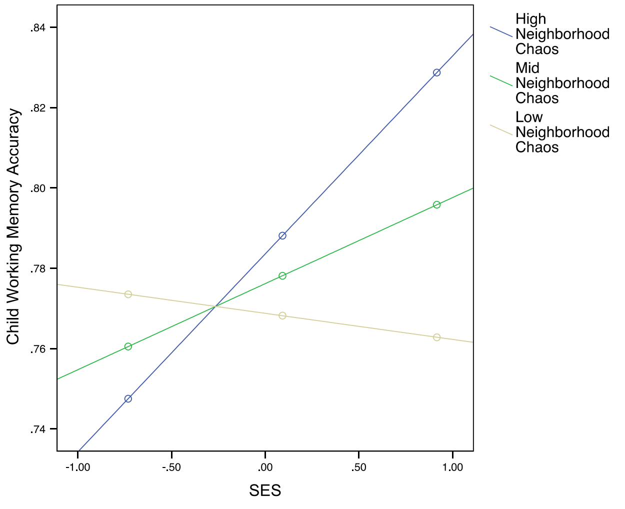

FIGURE 3 Interaction of socioeconomic status (SES) and neighbourhood chaos in predicting child working memory. This shows the relation of SES and child working memory at 1 standard deviation below the mean of neighbourhood chaos, at the mean, and at 1 standard deviation above the mean. At high levels of neighbourhood chaos, higher SES is related to better child working memory. Note that this is only a visual depiction of the interaction, neighbourhood chaos was tested continuously

TABLE 5 Model coefficients and summary information for moderation model of working memory

Antecedent	*B*	*SE* for *B*	B (standard)	*SE* for B	*p*
SES	.18	.08	.15	.12	.02
Neighbourhood Chaos	–.02	.03	–.09	.10	.50
SES × Neighbourhood chaos	–.07	.03	–.20	.10	.05
Child age	.01	.00	.40	.10	<.001
Language	.00	.00	.10	.12	.38
Nonverbal IQ	.00	.00	.22	.11	.04
Parent gender	.01	.03	.03	.10	.41
Constant	–.30	.24	.05	.10	.22

Abbreviation: SES, socioeconomic status.

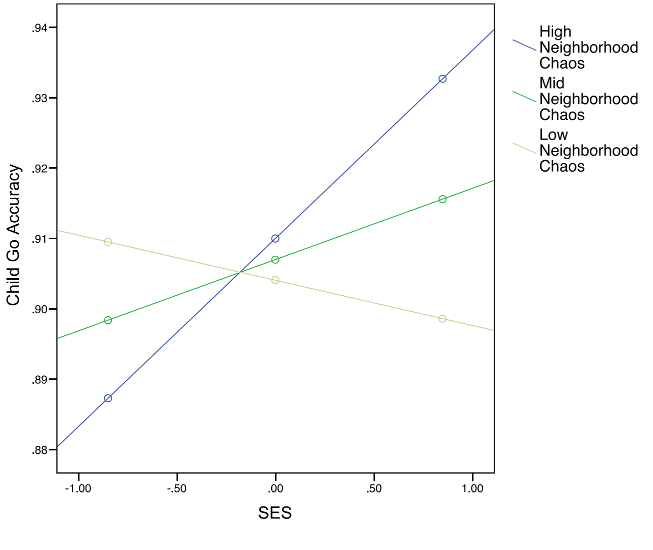

FIGURE 4 Interaction of socioeconomic status (SES) and neighbourhood chaos in predicting child go accuracy. This shows the relation of SES and child go accuracy at 1 standard deviation below the mean of neighbourhood chaos, at the mean, and at 1 standard deviation above the mean. At high levels of neighbourhood chaos, higher SES is related to better child go accuracy. Note that this is only a visual depiction of the interaction, neighbourhood chaos was tested continuously

TABLE 6 Model coefficients and summary information for moderation model of go accuracy

Antecedent	*B*	*SE* for Coeff	β	*SE* for β	*p*
SES	.10	.04	.12	.10	.02
Neighbourhood Chaos	–.01	.02	–.04	.10	.71
SES × Neighbourhood chaos	–.04	.02	–.20	.10	.03
Child age	.01	.002	.34	.09	<.001
Language	.00	.00	.17	.10	.10
Nonverbal IQ	–.00	.00	–.05	.10	.59
Parent gender	–.02	.02	–.12	.09	.21
Constant	.45	.13	.07	.09	<.001

Abbreviation: SES, socioeconomic status.

and go accuracy. Further, no contextual variables moderated the relation of SES and no-go accuracy: parental well-being ($B = -.03$, $p = .23$, $\beta = -.12$), household chaos, ($B = .02$, $p = .51$, $\beta = -.06$), or neighbourhood chaos ($B = -.02$, $p = .74$, $\beta = -.03$).

To ensure that the moderation results were not driven by outliers in individual variables or in relations between variables, Cooks distance was calculated for models with significant interactions described above. The conservative threshold of 4/n was used. Participants above this threshold for each model were excluded and the models were rerun. The interactions remained significant after excluding outliers, demonstrating that the results were robust to outliers.

Specifically, for the working memory model, six participants were above the threshold. When excluding these participants, a conditional process model, F (7, 75) = 10.13, $p < .001$, explained 48.60% of the variance in working memory and yielded a significant SES × Neighbourhood Chaos interaction ($B = -.08$, $p = .01$, CI:. -0.14 – –0.02; $\beta = -.25$, CI: –0.43 - -0.54). The interaction specifically explained 5.01% of the variance in working memory. For the go accuracy model, seven participants were above the threshold. When excluding these participants, a conditional process model, F (7, 95) = 4.75, $p < .001$, explained 25.93% of the variance in go accuracy and yielded a significant SES × Neighbourhood Chaos interaction ($B = -.05$, $p = .002$, CI:. -0.09 – –0.02; $\beta = -.31$, CI: –0.50 - -0.12). The interaction specifically explained 8.16% of the variance in go accuracy.

3.1 | Post hoc analyses

Given that parental perception of neighbourhood chaos moderated associations of SES and working memory as well as SES and go accuracy, we were interested to ascertain whether it was specifically parental perception of neighbourhood that was the critical variable, or whether parent-reported neighbourhood chaos may be serving as a proxy for a more objective measure of the neighbourhood context. Therefore, we constructed an objective index of neighbourhood quality for each family using U.S. Census tract information (Dubowitz et al., 2008) and conducted post hoc analyses using this variable as a potential moderator. Six measures were used to construct the objective index of neighbourhood quality: percentage of adults >25 years old with less than a high school education; percentage of unemployed males; percentage of households with an income below the poverty line; percentage of households receiving public assistance; percentage of households with children that are headed by a female; and median household income. All variables aside from median household income were reversed scored, therefore higher scores reflect higher neighbourhood quality (Cronbach's $\alpha = .87$). Variables were standardized and averaged into a composite (see Table 3 for descriptive information and Table 4 for correlations of neighbourhood quality with study variables). Four families were missing this variable, as they did not provide their addresses.

Moderation analyses were conducted using separate models to determine whether neighbourhood quality moderated the associations of SES and each EF measure. Child age, language, nonverbal IQ, and parent gender were included as covariates in all models. Neighbourhood quality did not moderate associations of SES and any of the EF measures: working memory (B = −.02, p = .28, β = −.12), go accuracy (B = −.02, p = .11, β = −.18), or no-go accuracy (B = .06, p = .10, β = 20).

4 | DISCUSSION

This study used a bioecological approach to assess how specific aspects of children's experiences may moderate the association of SES with child EF. Children aged 4.5 to 5.5 years completed EF tasks. Parents reported on household SES as well as levels of parental well-being, household chaos, and neighbourhood chaos. Neighbourhood chaos moderated the associations of SES and child working memory, as well as SES and sustained attention. Specifically, in high-chaos neighbourhoods, SES related to child EF, such that within high SES families, children exposed to higher neighbourhood chaos had better EF. Findings indicate the relevance of the neighbourhood environment and highlight the importance of examining the interplay of contextual factors with SES to better understand variation in child EF.

In high chaos neighbourhoods, SES related to child EF. Unexpectedly, examination of the interactions as shown in Figures 3 and 4 suggests that this association may reflect a benefit of higher neighbourhood chaos within high-SES families. It could be that for children in high-SES households, some level of challenge in the environment is beneficial. Indeed, some research suggests that an unpredictable environment may enhance working memory (Young, Griskevicius, Simpson, Waters, & Mittal, 2018). Further, in the animal literature, the benefits for cognitive development of mild or limited stressors are well established, when these stressors occur in the context of a generally supportive environment. For instance, young squirrel monkeys randomized to 1 hr a week of social isolation later performed better on inhibitory control tasks than those reared in a low stress control condition (Parker, Buckmaster, Justus, Schatzberg, & Lyons, 2005). Similarly, rat pups exposed to a novel environment without disruption of maternal care had enhanced spatial working memory in adulthood (Tang, Akers, Reeb, Romeo, & McEwen, 2006). Speculatively, high neighbourhood chaos in the context of growing up in a high-SES family may be analogous to these animal studies of the effects of limited stressors on EF. In the high-SES households, there are many resources available to help children cope, and neighbourhood chaos may expose children to situations that prompt them to develop and practice EF skills in a real-world setting. By contrast, children in lower SES households are likely to be exposed to more chronic and pervasive stressors (see for review, Blair & Raver, 2016). Children in lower SES households may not experience neighbourhood chaos as an isolated stressor but rather part of a constellation of stressors and have fewer resources at their disposal. Thus, the importance of neighbourhood chaos for child EF cannot be understood without taking SES into account.

Given the significant interaction between SES and parental perception of the neighbourhood, post hoc analyses were conducted using an objective measure of the neighbourhood context. Including this objective measure could help tease apart whether parental perception of the neighbourhood was important or whether parental perception was a proxy for more objective indices of the neighbourhood. Interestingly, the objective neighbourhood measure did not moderate the relation between SES and child EF. Thus, it was parental perception of their neighbourhood that was critical. The neighbourhood chaos measure assessed parents' perceptions of their neighbourhood, including physical and social characteristics (e.g., feeling safe, vandalism, and open drug activity), whereas the objective neighbourhood quality measure was based on census data and included items such as percentage of households with an income below the poverty line and percentage of households receiving public assistance. One study found that neighbourhood quality based on census data did not relate to cortisol functioning, but perceptions of the neighbourhood were related to cortisol functioning (Karb et al., 2012). In addition, aspects of the neighbourhood such as violence were related to cortisol functioning in children (Theall et al., 2017). Thus, it is possible that perceptions of the neighbourhood environment such as safety are especially important for both parents and children.

Although neighbourhood chaos moderated the associations of SES and working memory as well as SES and go accuracy, neighbourhood chaos did not moderate the relation of SES and inhibitory control. This is surprising as we anticipated that there would be an interaction between neighbourhood chaos and SES for all EF measures. It could be that inhibitory control is an emergent EF skill at this age and is challenging for most children. Thus, subtle environmental interactions may be more pronounced in older children when inhibitory control is better established. Further, it is possible that different aspects of the environment may matter for different cognitive functions. Future research including additional components of EF, such as cognitive flexibility, as well as assessing these constructs at older ages could help explore these possibilities. Results underscore the importance of looking across multiple domains of EF, as interactions may not be the same for all aspects of EF, as seen in the current study.

Higher parental well-being was associated with better child working memory, consistent with past research (Gueron-Sela et al., 2018; Hughes et al., 2013; Huhtala et al., 2014). Yet our measure of parental well-being, comprising depression and parenting stress, did not interact with SES in predicting child EF. It could be that the role of parental well-being is more of a main effect in relating to child EF, as opposed to a factor that interacts with SES. Additionally, only 13.22% of parents met criteria for depression. It could be this lack of variability in parental depression that contributed to the non-significant interaction between parental well-being and SES. Future studies including a sample with higher rates of depression are needed to further understand these relations.

Household chaos also did not moderate relations of SES and child EF and did not relate to EF directly. Past research found that higher levels of household instability and disorganization indirectly linked to worse child executive functioning through parenting behaviours (Martin et al., 2012; Vernon-Feagans et al., 2016). However, Vernon-Feagans et al. (2016) assessed the household environment during a comprehensive home visit and oversampled to include a majority of families that were low-income. It is possible that our parent report measure did not fully capture household chaos in the home within our sample that spanned the SES spectrum. Additionally, in the current study, we used the short form of the CHAOS questionnaire. It is possible that this shortened form did not pick up on as much variability as there actually is in the home. Future studies using the longer CHAOS questionnaire or conducting an in-person assessment are needed to better understand the role of household chaos for child EF.

A strength of this study was the inclusion of variables indexing multiple aspects of the child's environment and experience, consistent with the bioecological model of human development (Bronfenbrenner & Morris, 2007). Past studies have assessed effects of cumulative risk on child socioemotional and cognitive outcomes (Li-Grining, 2007; Lima et al., 2010). Our study builds on these findings and elucidates one specific aspect of risk, neighbourhood chaos, which interacts with SES. Further, we controlled for child age, receptive language, and nonverbal IQ in our moderation analyses. This suggests that SES and neighbourhood chaos matter for EF specifically rather than just for general cognitive abilities.

Although this study sheds light on factors that matter for child EF, there are limitations and multiple future directions. For example, additional aspects of the child's environment are likely relevant for early EF and should be assessed in future studies. Specifically, risk and resilience factors, such as violence exposure, discrimination, sensitive parenting, and parent stress physiology, may also moderate associations between SES and child EF. These factors are important to explore in future research to build on and expand the findings of this study. In addition, this cross-sectional study takes a first step in demonstrating the possible importance of neighbourhood quality for child EF. However, Bronfenbrenner also emphasized the role of time by context interactions for development (Bronfenbrenner & Morris, 2007). This is supported by empirical research demonstrating a longer duration of time spent in poverty has more detrimental effects for child EF, compared with spending less time in poverty (Raver et al., 2013). Therefore, longitudinal research assessing these constructs is necessary to understand how SES and neighbourhood chaos may interact with time in impacting EF. Furthermore, this study included a sample that spanned the SES spectrum, given that a recent meta-analysis demonstrated that differences in EF are evident across the SES spectrum (Lawson et al., 2017). However, future studies including samples that overrepresent low-SES families is an important next step to further investigate how environmental factors, specifically parental well-being and household chaos, interact with low SES specifically in relation to child EF.

SES effects occur in a dynamic context, and family and neighbourhood level factors may have different implications for children depending on the SES context. Therefore, this study aimed to disentangle how specific aspects of the early environment may interact with SES in relating to child EF. Here, we expand on the established literature linking SES and child EF (Blair et al., 2011; Farah et al., 2006; Lawson et al., 2017; Noble et al., 2005; Raver et al., 2013) by showing an interaction of SES and neighbourhood chaos, with the initially counterintuitive finding that in the context of high SES, neighbourhood chaos was positively associated with EF. In their recent systematic review of the role of environmental factors in children's cognitive development, Del Carmen Ruiz, Quackenboss, and Tulve (2016) contended that research focusing on single stressors can obscure the full picture by leaving unknown how specific mixtures of environmental factors may interact additively or synergistically and stressed the need to examine multiple factors. Our findings underscore this call to action, as results indicate that factors such as neighbourhood quality may operate differently and have distinct implications for child EF depending on the SES context.

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