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- We examine how toddlers' self-regulation relates to SES and pre-academic skills.
- Two self-regulation factors emerged: parent-reported and observational measures.
- Observed self-regulation measures explained SES variation in math and vocabulary.
- Parent-reported self-regulation was unrelated to SES, math, and vocabulary.

Self-Regulation in Toddlers and the Emergence of Pre-Academic Disparities

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Abstract

A growing body of research has examined how children's self-regulation during early and middle childhood mediates SES disparities in academic achievement. Evidence suggests that these self-regulation skills begin developing even earlier, during the toddler years, but more work is needed examining how different measures of self-regulation relate to key constructs such as socioeconomic status (SES) and toddlers' pre-academic skills. In this online study, we examine multiple approaches to measuring self-regulation using confirmatory factor analyses and assess the extent to which self-regulatory skills help explain SES differences in early math and language skills among a sample of 158 two- and three-year-old children. Self-regulation was assessed through a battery of parent- and examiner-ratings. Children's counting, cardinality, and vocabulary skills were measured online through direct assessments and parent surveys. Two self-regulation factors emerged representing parent-reported and observational measures, and only observational measures of self-regulation mediated associations between SES and children's math and language skills. Parent-reported self-regulation was not uniquely related to SES or children's pre-academic skills, underscoring the need for careful consideration of how self-regulation is measured among toddlers when examining its associations with pre-academic skills.

Keywords: self-regulation, socioeconomic status, early math, vocabulary, toddlers

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- We examine how toddlers' self-regulation relates to SES and pre-academic skills.
- Two self-regulation factors emerged: parent-reported and observational measures.
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Self-Regulation in Toddlers and the Emergence of Pre-Academic Disparities

1. Introduction

Children's ability to regulate their emotions and behaviors is critical for not only socioemotional outcomes but cognitive development as well (McClelland & Cameron, 2012). One central way that self-regulation has been examined in past research with children in preschool and kindergarten is as a mechanism giving rise to the early emergence of socioeconomic variability in children's academic skills (Evans & Rosenbaum, 2008; Finders et al., 2021; Raver, 2012). Socioeconomic status (SES) tends to positively predict self-regulatory skills, which in turn relate to academic achievement. However, these mediational pathways predicting early cognitive and pre-academic skills are rarely examined before preschool or kindergarten, and yet early precursors of children's abilities to regulate their emotions and behaviors, as well as the precursors of later formal academic achievement, are seen much earlier in development (Gagne, 2017; Kopp, 1982).

Individual differences in self-regulation skills observed early in development tend to be less pronounced than later in development (Calkins & Fox, 2002; Raikes, Robinson, Bradley, Raikes, & Ayoub, 2007), requiring more sensitive measures. Additionally, more work is needed comparing methods of assessing these early skills to help researchers and practitioners determine the assessments best suited to their needs. Several measures have been used in past work to assess toddlers' self-regulation, including parental reports of children's attention and inhibitory control, examiner ratings of children's behaviors based on brief observations, and direct tasks that require children to demonstrate their ability to self-regulate (see Allan, Hume, Allan, Farrington, & Lonigan, 2014). Furthermore, it remains unknown to what extent toddlers' self-regulation skills play similar roles in the development of socioeconomic variability in early pre-

academic skills. In this study, we explore how multi-informant measures of self-regulation among toddlers are related to one another, and how these early self-regulatory skills might contribute to individual differences in pre-academic skills related to SES through an online study. We also examine the extent to which parent or assessor ratings of toddlers' self-regulation mediated associations between SES and pre-academic skills. Thus, this study offers increased specificity on how early differences in achievement emerge and directions for future intervention work.

1.1. Self-Regulation as a Mediator of SES and Academic Skills

Self-regulation during childhood is a complex, multifaceted construct and is measured using observational tasks and surveys that tap into a wide range of skills. Two general approaches to conceptualizing and measuring these abilities are common in past work (see Liew, 2012, for review). On the one hand, research stemming from the temperament literature often examines effortful control, or children's voluntary attention and inhibition of behaviors (Liew, 2012). Alternatively, similar abilities are described in the cognitive development literature as executive function, which include subdimensions of inhibitory control, attention shifting, and working memory (see Garon, Bryson, & Smith, 2008). Although these approaches and the corresponding measures are theoretically and empirically distinct, they also overlap considerably and prior research has proposed links between these dimensions (see Aksan & Kochanska, 2004; Rothbart, Derryberry, & Hershey, 2000). Thus, in the present study, we include both temperamental differences in effortful control and cognitive executive functions as aspects of self-regulation.

As noted above, self-regulation has been posited to be a key mechanism through which family SES relates to children's academic skills among four-year-old children (Sektnan et al.,

2010) as well as through elementary and middle school (Evans & Rosenbaum, 2008). Related literature has implicated self-regulation in explaining the early income-achievement gap and school readiness at kindergarten entry (Finders et al., 2021; Wanless et al., 2011). Below, we discuss these theorized pathways from SES to self-regulation and from self-regulation to achievement in greater detail, followed by a review of how self-regulation can be measured in toddlers and may relate to SES disparities in children's earlier pre-academic skills.

1.1.1. Mediational Pathways in Preschool and Beyond

Several explanations for why SES might relate to self-regulation have been suggested in past research. Experiences of adversity and stress brought on by poverty increase stress hormones, like cortisol, to effectively undermine the development of self-regulation in early and middle childhood (Blair, 2010; Blair & Raver, 2012). Lower-income children confront a greater number and variety of physical and psychosocial stressors compared to their higher-income peers, including household instability and negative life events, parental depression, and less consistent and responsive parenting practices (Li et al., 2017; Montroy et al., 2016). The accumulation of stressors may have direct deleterious effects on children's self-regulatory skills (Burchinal et al., 2006; Evans & Kim, 2013; Gutman et al., 2003; Rauh et al., 2003; Rouse & Fantuzzo, 2009). However, children are not the only family members experiencing these increased stressors and negative life events; similar processes may have deleterious effects on parents' health and well-being, which indirectly impacts children via less developmentally appropriate parenting practices with their young children. Finally, children in lower income households may also experience lower quality home learning environments, which has also been linked to lower self-regulatory skills (Mistry et al., 2010; Rosen et al., 2020).

Additionally, self-regulation is a foundational skill for math, language, and literacy skills during early and middle childhood (Caughy et al., 2018; Fuhs et al., 2013; McClelland & Cameron, 2011). More advanced language skills in preschool are bidirectionally related to greater self-regulatory skills as children require language to better name their current mental state and change it depending on the context (Bohlmann et al., 2015). Relatedly, research suggests that early math skills (e.g., identifying numerals, counting, labeling sets) may specifically require greater self-regulatory skills as, for younger children, math requires more active reasoning than it does later in development (Birgisdottir et al., 2020; Blair et al., 2015; Connor et al., 2016). Little research has explored whether these associations between self-regulation and academic skills are apparent in toddlerhood when math and language skills are rapidly growing.

1.1.2. Self-Regulation in the Toddler Years

Although self-regulation, and particularly more cognitive aspects of regulation such as executive function, are most often studied in the preschool years and beyond, many foundational self-regulatory skills emerge and undergo considerable development during infancy and toddlerhood. For example, past work demonstrates that infants' abilities to focus and sustain their attention grows during the first years of life, such that children become more able to selectively attend to stimuli or shift the focus of their attention (see Garon et al., 2008). Similarly, basic self-regulation related skills underpinning working memory and response inhibition begin to emerge in the first two years of life, followed by a rapid maturation of these abilities as they are further internalized during early childhood (Gagne, 2017; Garon et al., 2008). Specifically, as children progress from infancy through toddlerhood, their self-regulatory capacities progress from more rudimentary self-control (e.g., compliance with demands) to more

formal self-regulatory behaviors (e.g., monitoring one's own behavior; Kopp, 1982). From age two onwards, children demonstrate more complex self-regulatory capacities involving delay and response inhibition in addition to compliance (Berger et al., 2007; Kochanska et al., 2001; Kopp, 1982).

Common methods for measuring self-regulation in toddlers include adult-report measures of self-regulatory behaviors or abilities, which often reflect parent ratings or assessor (e.g., trained researchers, teachers, daycare providers) ratings of self-regulatory behaviors or abilities. Many of these self-report measures, typically in questionnaire format, require parents and teachers to rate toddlers' typically occurring behaviors within the home and daycare/school context (Allan et al., 2014). Two such questionnaire measures commonly used in this literature are the Children's Behavior Questionnaire (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001), specifically the Inhibitory Control subscale, and the Inhibition subscale from the Behavior Rating Inventory of Executive Function-Preschool Version (BRIEF-P; Gioia, Ebsy, & Isquith, 2003).

A similar approach to measuring self-regulation is to have research staff rate young children's behaviors during cognitively and emotionally demanding tasks. An example of such measures is the Preschool Self-Regulation Assessment-Assessor Report (PSRA-AR; Smith-Donald, Raver, Hayes, & Richardson, 2007), in which self-regulatory capacities along dimensions of attention, impulsivity, and emotion regulation are rated by a trained assessor following a direct observation of the child. Although both parent-ratings and assessor-ratings rely on an adult's interpretation on the child's behavior, these ratings differ in the scope of behaviors observed as well as the biases and expectations of the raters themselves.

Each of the differing approaches to measuring toddlers' self-regulation has their own strengths and weaknesses. Less is known about how measures generated with these different approaches relate to one another. Past research demonstrates that among preschool and kindergarten students, parent ratings of self-regulation are moderately correlated with observed behaviors (Howard et al., 2019; Ponitz et al., 2009), but fewer studies have explored how measures relate to one another among younger children (see Geeraerts et al., 2019). These tasks each assess similar aspects of children's behavior, including the ability to attend to rules and instructions, inhibit undesired responses or behaviors, and regulate emotions. To the extent that these behaviors are consistent across differing physical and social settings, we expect that parent-reported and assessor-rated self-regulation will reflect a single underlying construct (i.e., load on a single latent factor). However, given the methodological differences noted above, it is also possible that the behaviors seen and evaluated by parents may differ from those observed by other adults during the testing session. If so, parent-reported behaviors may reflect a unique component of self-regulation distinct from assessor ratings that were based on a narrower window of time and under more constrained circumstances.

1.1.3. Extending Mediational Models to Toddlerhood

Several studies have demonstrated that SES differences in self-regulation appear early in development. SES indices that include income, parental education, and employment predict attentional control in infants and toddlers, which in turn is related to more traditional measures of self-regulation such as executive function and effortful control during preschool (Brandes-Aitken et al., 2019). Similarly, among toddlers and young children, SES factors predicted children's early executive control but not delay of gratification; although these dimensions of effortful

control or self-regulation are related, the former may require more cognitive control and attention rather than inhibition of behavior or desire (Li-Grining, 2007).

Not only are children's early self-regulatory skills already developing among two- to three-year-old children, but these children also already display some early academic building blocks critical for later school success. In the domain of math, children's understanding of cardinality increases incrementally, such that children first understand the meaning of the word "one" around two years of age, followed by the word "two" a few months later, and so on, before they are able to generalize the cardinality principle to any number word (Wynn, 1990, 1992). As such, there are individual differences in toddlers' progress along this developmental progression as children become able to produce as well as recognize various set sizes (Silver et al., 2021). Additionally, at this age many children already have knowledge of the count list and the order of number words (Ip et al., 2018; Wang & Feigenson, 2019). These foundational number skills during the preschool years have been linked to children's math achievement in elementary school (Geary et al., 2018; Nguyen et al., 2016). Similarly, although early precursors to reading, such as letter and sound recognition, may not develop until later in early childhood, considerable variability can be seen in the vocabularies of two- and three-year-old children. One study examining children's expressive vocabulary size at age two found that children who used more words as toddlers showed not only increased later expressive vocabulary but also stronger reading comprehension and literacy skills, and these associations were seen through fifth grade (Lee, 2011).

Furthermore, some evidence suggests that SES differences in vocabulary and early counting skills are sizeable by 24 months of age, with gaps ranging between a third to half a standard deviation between children above and below 200% of the poverty guideline in the U.S.

(Halle et al., 2009). As such, toddlers are already developing the building blocks for later academic achievement, and SES differences in these skills have emerged. However, the role that self-regulation may play in the development of these disparities is unknown.

1.2. The Current Study

In this study, we aim to extend past work addressing the development of self-regulatory skills in toddlers, particularly their role in emerging SES-achievement disparities. We include a range of measures of self-regulation from multiple sources as well as direct assessments of children's pre-academic skills to obtain rich data on these rapidly developing skills. Due to the COVID-19 pandemic, all data were collected via online surveys and videoconferencing calls. Specifically, we answer two research questions: First, how do parent-report and assessor-rating measures of self-regulation in toddlers relate to one another? Second, to what extent do components of self-regulation mediate SES disparities in children's pre-academic skills? We expect that measures of toddlers' self-regulation will be represented by a single factor that more robustly represents children's self-regulation across settings and that these self-regulatory skills will mediate associations between SES and children's math and language skills.

2. Methods

2.1. Participants

Participants in the [STUDY NAME BLINDED] study included 158 toddlers (78 girls) and one of their caregivers recruited from the greater metropolitan area of a mid-sized city in the northeastern United States. We note that all families were located in this region given that assessment materials had to be driven to and retrieved from children's homes. Data collection was conducted from 2020-2022 and completed online due to pandemic-related restrictions on in-person interactions. Children were on average 2 years and 7.90 months old at the start of the

study (*SD* = 2.50 months, range = 2 years 3.92 months - 3 years 2.47 months). Caregivers were most often biological mothers (*n* = 149), but several fathers (*n* = 8) and one legal guardian also participated with their child. For clarity, all caregivers will be referred to as parents. Most parents in this study were White, non-Hispanic (79%), with others identifying as Black (13%), Hispanic/Latino (3%), Asian (2%), or another race (3%). The majority of parents were married (80%) and had obtained at least a Bachelor's degree (76%). Additionally, 22% of families were low-income (i.e., earning below 200% of the poverty line), whereas 32% earned between 200% and 400% of the poverty line and 45% earned over 400% of the poverty line. The majority of respondents were employed at the time of this study (67%), with 71% of these parents working over 30 hours per week. Of the target children, 45% were enrolled at a childcare center, with children attending roughly 30 hours per week on average. Most parents reported that English was their first language (95%), and all remaining parents reported that their English was proficient or advanced. Parents also reported what languages children heard spoken live (i.e., not on a TV program), and 94% of children heard English 90% or more of the time, 4% heard English less than 90% of the time but still more often than other languages (Spanish, Pashto, or Twi), and 1% heard another language (Spanish or Tamil) more often than English. Descriptive statistics for the full sample are shown in Table 1.

2.2. Procedure

This study was conducted entirely online due to the COVID-19 pandemic through a combination of video conferencing calls, phone calls, and online surveys. After providing informed consent, research assistants delivered all necessary study materials to families' homes, including a laptop and wifi hotspot, if needed. These materials were then used for two Zoom calls with a research assistant and a parent-child dyad, each of which lasted around half an hour.

During these calls, children completed several cognitive assessments as well as observational tasks with a parent, which were not used in the present study. During the first call, children completed all three of the number skills assessments (i.e., the Give-A-Number, Point-to-X, and counting tasks) in addition to two structured observation tasks. After each call, researchers completed a rating of the child's self-regulation, described in more detail below. Parents were then sent an online survey to complete addressing their demographics, children's vocabulary knowledge, ratings of their child's self-regulation behaviors, and a variety of other psychological scales addressing factors such as mental health (e.g., Work and Family Life Questionnaire, Greenberger & Goldberg, 1989; Center for Epidemiologic Studies Depression Scale, Radloff, 1977), resource-related stressors (e.g., National Center for Health Statistics Food Insecurity scale; Confusion, Hubbub, and Order Scale, Matheny et al., 1995), and parental beliefs and activities (e.g., Home Activities Scale, LeFevre et al., 2009) Surveys were completed in roughly an hour on Qualtrics.

Families were recruited from online research registries, university and community announcements, social networking sites (e.g., targeted Facebook advertisements based on location), and from local preschool and community organizations such as museums and libraries. In all cases, families were given brief information about the study, including that the goal was to study children's early learning with parents of two- to three-year-olds and that all data collection would be completed online. Families then contacted the research team by phone or email in order to receive more information, at which point a team member completed a brief screening phone call to ensure that the family was eligible (e.g., that children fell into the correct age range and that adults were legally able to provide consent for the child participating) and scheduled study components. In total, families were compensated $100 for participation in this study.

2.3. Measures

2.3.1. Socioeconomic status (SES).

Parents reported their educational attainment and yearly household income as part of the online questionnaire as well as through a short paper demographic survey, which was used when responses were missing from the online questionnaire. Income was reported for the prior year and was log-transformed based on past work demonstrating non-linearity in associations between income and child outcomes (Votruba-Drzal, 2006). The highest level of education that parents could report included high school diploma or GED (general equivalency diploma), vocational/technical training, some college but no degree, Associate's degree, Bachelor's degree, some graduate work, Master's degree, other advanced degree, or none. Parent education was then converted to a continuous variable reflecting the years of completed education, ranging from less than a high school diploma or GED = 11 years to a graduate degree = 18 years. The natural log of household income and years of parental education were then standardized and averaged to form an SES composite variable.

2.3.2. Self-regulation.

As part of the online survey, parents completed three subscales of the Early Childhood Behavior Questionnaire – Short Form (ECBQ-S; Putnam, Gartstein, & Rothbart, 2006): *attentional focusing*, *attentional shifting*, and *inhibitory control*. Caregivers were instructed to rate the frequency of various behaviors that their child displayed in the past two weeks on a 7-point Likert scale (1 = Never, 2 = Very rarely, 3 = Less than half the time, 4 = About half the time, 5 = More than half the time, 6 = Almost always, 7 = Always), or indicate that the behavior did not occur. The *attentional focusing* composite was created from averaging the scores of 6 items, such as "When playing alone, how often did your child play with a set of objects for 5

minutes or longer at a time?" (alpha = .69). The *attentional shifting* composite was derived from averaging the ratings of 8 items, e.g., "During everyday activities, how often did your child easily shift attention from one activity to another?" (alpha = .71). Finally, the *inhibitory control* composite was created from averaging the scores of 6 items, including "When asked NOT to, how often did your child touch an attractive item (such as an ornament) anyway?" (alpha = .71). These subdimensions have been widely used and validated among infants, toddlers, and young children (e.g., Putnam et al., 2001, 2008).

Additionally, at the end of each testing session, the researcher who interacted with the child rated the child's behavior during the assessment battery using a modified version of the Preschool Self-Regulation Assessment (PSRA; Smith-Donald et al., 2007). Each item referred to a general description of behaviors or characteristics that researchers may have observed throughout testing and included a scale of 0 to 3. For example, one item described the extent to which the "child has difficulty waiting between tasks," where 0 = *Child waits patiently for new tasks to begin, shows relaxed body posture during transitions* and 3 = *Transitions between tasks made difficult because of child's activity level/impulsivity*. Composite measures representing subdomains of children's self-regulatory behaviors on each day of testing were derived by averaging a subset of items on the PSRA. The *attention regulation* composite was created by averaging the scores of 2 items, e.g., "Pays attention during instructions and demonstrations" (alpha = .79 on day 1 and .84 on day 2). The *impulsivity* composite was created by averaging the scores of 6 items, e.g., "Refrains from indiscriminately touching test materials" (alpha = .89 on day 1 and .89 on day 2). These composites were based on factor analyses of this measure with a sample of four-year-old children (Daneri et al., 2018). Past work has validated this scale and shown that it operates similarly across sex, income, and race/ethnicity for children between three

and five years of age (Daneri et al., 2018; Smith-Donald et al., 2007); however, to our knowledge this measure has not been used with younger children.

2.3.3. Pre-academic skills.

Children completed several direct assessments of their pre-academic skills during the first video conferencing call, including two tasks tapping their knowledge of the cardinal meaning of number words, e.g., knowing that the word "two" refers to sets of two items. For the *Give-A-Number* (Give-N; Wynn, 1992) task, parents were instructed to place a paper plate and a pile of eight toy fish between their child and the computer screen. On each trial of the task, researchers asked the child to place a specific number of fish on the plate (e.g., "Can you give the bear one fish to eat?") and confirmed the child's response regardless of accuracy (e.g., "Is that one fish?"). Researchers requested one to six fish and the number of fish requested followed a titration procedure. They started the task asking for one fish and then two fish, regardless of children's accuracy on the first trial. On subsequent trials, they increased the quantity requested by one for each trial if children responded correctly on the previous trial and decreased the quantity requested by one if children responded incorrectly. The task ended after children responded correctly at least twice for a specific number N and failed twice at N+1. If children failed to give even one fish correctly, the task ended after they failed on this number twice and they were given a score of 0 (n = 19). If children successfully gave six fish, they were not asked for more but instead asked for six fish again to test their reliability. If they succeeded twice, the task ended and they were given a score of 6 (n = 7). Children's knower-levels were calculated based on the highest number that they correctly produced at least twice. The Give-N task is highly reliable at differentiating children's knower-levels, as children who completed the titrated and non-titrated

versions of the task are generally classified as the same knower-level (weighted kappa = .87; Marchand & Barner, 2020).

For the *Point-to-X* task (Wynn, 1992), children were given a three-ringed binder containing laminated images. Before the actual test trials, children completed two practice trials in which the researcher asked the child to point to non-numerical matches (e.g., a glass of milk and a tree). During each test trial, children were instructed to look at two pictures, one on each side of the binder's rings, and point to the image that contained the number of items that the researcher requested. For instance, children were shown two images of a plate of cookies, one with one cookie and the other with three cookies, and they were asked, "Which has one cookie?" Children completed 12 trials in which the number of items stated ranged from 1 to 10. We calculated children's percentage of correct responses on the test trials (alpha = .72). Past work demonstrates close alignment between this task and other measures of early number skills and cardinality understanding (Silver et al., 2021; Wynn, 1992).

Children also completed a *counting* task in which they were asked to count out loud on their own, i.e., "Can you count for me?" If children did not begin counting independently, researchers counted up to two to get them started, e.g., "One, two… what comes next?" Children were provided with a sheet of paper containing 24 dots and this was used to help them start counting if they were reluctant to do so. If children stopped after reaching a particular number, the researcher prompted them to continue, i.e., "What comes next?" Children were permitted to correct their mistakes or start over if they indicated that they made an error. They were stopped once they made a mistake or reached 100. We obtained children's count list knowledge as the highest number that they counted to without making a mistake. Parents were also asked to report how high their children could count when completing the online survey, which was highly

correlated with performance on this task, $r(103) = .70$, $p < .001$, indicating that observations of children's counting reflected a stable ability.

To assess early language skills, parents completed the *Developmental Vocabulary Assessment for Parents* (DVAP; Libertus, Odic, Feigenson, & Halberda, 2015) as part of the electronic questionnaire. They were given a list of 212 words originally taken from the Peabody Picture Vocabulary Test (4th edition; Dunn & Dunn, 2007). These words increased in frequency and complexity (e.g., "girl," "jumping," "parallelogram") and parents were asked to indicate which of the listed words they had heard their child say, without asking their child whether they knew the words. Parents were allowed to indicate words that their child might have used with a different pronunciation or as a different part of speech (e.g., saying "sleep" instead of "sleeping"). The DVAP is a valid measure of children's productive vocabulary, as children's DVAP scores significantly correlate with their scores on an experimenter-administered vocabulary assessment (Libertus et al., 2015). We derived the total number of words that parents indicated as a measure of children's expressive vocabulary.

2.3.4. Covariates

In addition to these key variables of interest, models included controls for demographic characteristics of families that tend to be associated with SES as well as children's self-regulatory and pre-academic skills. Specifically, children's age in years was calculated based on the date of the first research visit, and the race/ethnicity of the participating parent was dichotomized to reflect whether parents were White/Non-Hispanic (coded as 0) or Black, Hispanic/Latino, Asian, or another race (coded as 1).

2.4. Analysis Plan

In order to examine how parent-report and assessor-rating measures of self-regulation in toddlers relate to one another (RQ1), we first tested the latent factor structure of self-regulation measures using confirmatory factor analysis (CFA) in Mplus Version 8 (Muthén & Muthén, 2017). We first assessed whether all measures of self-regulation loaded onto a single factor and then examined whether observed and parent-reported measures loaded on separate factors. We then created latent factors representing children's early math and language skills. The latent factor for math skills included performance on the Give-N, Point-to-X, and counting tasks as indicators; a single measure of child language was collected, which was used as our language outcome. This model of pre-academic skills had good model fit, $\chi 2(2) = 4.13$, $p = .127$, RMSEA = .084, CFI = .981, SRMR = .039, and was used in all further analyses.

To test our second research question, we used these latent factors in a structural model to test for indirect effects of SES on pre-academic skills through self-regulation. In this full structural model, the latent math variable and the language variable were regressed on latent measures of self-regulation (based on the results of the CFA), the observed SES composite measure, and covariates. Latent self-regulation measures were regressed on SES and covariates as well. Indirect effects were calculated using the model indirect command, and confidence intervals were estimated using the bcbootstrap command with 2000 draws. For bootstrapped estimates, we present 95% confidence intervals. In addition to this model, the structural model was estimated with both pre-academic latent variables and self–regulation latent variables regressed on covariates (i.e., child age and parent race/ethnicity).

For all models, full information maximum likelihood estimation was used to handle missing data (Enders & Bandalos, 2001). Additionally, in order to include cases with missing data on exogenous predictors, these observed variables (i.e., SES, child age, and parent

race/ethnicity) were modeled as single indicator latent variables, with a factor loading of 1 and the residual variance in the observed indicator constrained to 0. Missing data ranged from less than 1% for the SES composite variable to 29% for the child counting assessment. Of the full sample, 53% of cases were missing data on no variables, with an additional 22% of all cases missing data on only one variable and 10% of cases missing data on two variables. Model fit was evaluated with conventional fit indices (i.e., non-significant chi-square, RMSEA < .06, CFI > .95, and SRMR < .08; Hu & Bentler, 1999).

3. Results

3.1. Factor Structure of Self-Regulation

Our first research aim in this study was to understand how parent-report and assessor-rating measures of self-regulation in toddlers related to one another. We hypothesized that measures of toddlers' self-regulation would be best represented by a single factor, and so as a first step, measures of children's early self-regulation were estimated as loading on a single factor. Additionally, we tested whether observer ratings of children's attention and inhibitory control within a single day would be correlated with one another, and so we estimated residual correlations between observer ratings on the PSRA within days of testing. However, this model did not fit the data well, $\chi2(12) = 54.03$, $p < .001$, RMSEA = .149, CFI = .925, SRMR = .082. We then estimated a two-factor model of self-regulation, with measures relying on observer ratings loading on one factor and parent reports on a second. This new specification resulted in a well-fitting model, $\chi2(11) = 12.85$, $p = .303$, RMSEA = .033, CFI = .997, SRMR = .044. Additionally, we tested a two-factor model without residual correlations between PSRA assessments, which resulted in a significant decrement in model fit, $\Delta\chi2(2) = 24.57$, $p < .001$. Thus, residual correlations were retained and two latent factors representing children's self-

regulation from observer reports and parent reports, respectively, were used in subsequent models. These latent factors are shown in the structural model (Figure 1).

3.2. Structural Model of SES, Self-Regulation, and Pre-Academic Skills

To assess the extent to which self-regulation mediated associations between SES and pre-academic skills, a structural model was estimated using two factors representing parent-report and observed self-regulation and two factors representing math and language skills, as well as children's age and parental race/ethnicity as covariates. We had predicted that self-regulation would mediate associations between SES and children's math and language skills. This model had good fit to the data, $\chi 2(58) = 61.21$, $p = .362$, RMSEA = .019, CFI = .996, SRMR = .055. As shown in Figure 1, SES was significantly and positively related to children's self-regulation, as measured through researcher ratings. Specifically, a standard deviation (SD) increase in SES was associated with a .20 SD increase in self-regulation. In contrast, the latent measure of self-regulation drawn from parent-report measures was not significantly related to SES. Self-regulation reported through observational tasks was also significantly related to children's math and language skills. A one SD increase in observational measures of self-regulation was associated with a .30 SD increase in math skills and a .41 SD increase in language. Although parent-reported self-regulation measures were positively related to pre-academic skill outcomes, these pathways did not reach statistical significance.

Finally, we examined indirect effects of SES on pre-academic skills through self-regulation. Based on bootstrapped estimates, the standardized direct effect of SES on math skills, controlling for self-regulation and covariates, was not significant, estimate = 0.09, CI = [-0.09, 0.26]. However, the overall indirect effect of SES on math through self-regulation was significant, estimate = 0.09, CI = [0.01, 0.20], which was driven by a significant indirect effect

through researcher-reported measures, estimate = 0.06, CI = [0.004, 0.16]. In contrast, the indirect effect through parental-report measures was not significantly different from 0, with a value of 0.03, CI = [-0.004, 0.20]. Bootstrapped estimates indicated that there was a significant total effect of SES on vocabulary of 0.42, CI = [0.25, 0.57], which was primarily direct, with an estimate of 0.33, CI = [0.20, 0.47]. However, the total indirect effect through latent measures of self-regulation was also significant, estimate = 0.09, CI = [0.01, 0.18]. As with math skills, the indirect effect of SES on vocabulary was attributable to researcher-reported measures, estimate = 0.08, CI = [0.01, 0.19], whereas the indirect effect through parent-report measures was not significant, estimate = 0.004, CI = [-0.02, 0.09].

4. Discussion

In this study, we examined the extent to which measures of early self-regulation skills related to one another and whether these measures helped to explain SES differences in toddlers' pre-academic skills. Several important findings emerged from these analyses: first, self-regulation measures in the early years loaded on two distinct yet correlated factors based on assessment modality: parent-report measures of children's self-regulation, and researcher ratings based on observations of children's behaviors. Researcher-ratings of toddlers' self-regulation were positively and significantly related both to SES and to concurrent math and language skills, and indirect effects of SES on pre-academic skills were detected through the self-regulation latent variable based on researcher-ratings. In contrast, parent-reported self-regulation measures were not significantly related to SES or to math or language skills when controlling for covariates. Finally, although SES was positively related to language skills, SES did not directly predict toddlers' math skills, as this association was fully indirect.

4.1. Dimensions of Early Self-Regulation

We attempted to model self-regulation as a single factor based on different types of measures but found that two factors of self-regulation were more appropriate. Specifically, one factor was based on parents' reports of children's behaviors and the other on researcher ratings of observed behaviors during the assessment batteries. Both factors included similar conceptual dimensions of self-regulatory skills, such as attention and inhibition, and so the difference between these factors was primarily methodological, although it is possible that measures may have also differed in whether they addressed more temperament-based regulation or cognitive control. In comparing these methods, both have their strengths and weaknesses. The parent-report measures may have been biased by parents' perceptions of their children, expectations and beliefs about what is typical for a child of this age, and social desirability biases, such that parent reports could be less objective than the observational measures. Alternatively, parents likely drew their ratings from a wider range of experiences with the child in more varied settings, resulting in more ecologically valid ratings than those based only on children's observed behavior during the testing sessions. Indeed, children's ability to self-regulate appears to be task- and situation-specific, such that parents and researchers observe different behaviors from the same child (see McClelland & Cameron, 2011, for discussion). Notably, these two latent variables were significantly and positively correlated with one another, as were many of the individual indicators across factors at the bivariate level in Table 1. These positive associations between researcher- and parent-reported measures of self-regulation are consistent with past research with two- to three-year-old children (Geeraerts et al., 2019) as well as among preschoolers and kindergarteners (Howard et al., 2019; Ponitz et al., 2009).

Despite the moderate association between the self-regulation factors seen in this study, only researcher-reported measures of toddlers' self-regulation were significantly related to SES

and to pre-academic skills. Although some past research using parent-report measures of children's self-regulation has established associations with SES and academic outcomes among older children (Sektnan et al., 2010), most of the work examining these pathways has relied primarily on observational measures (Caughy et al., 2018; Finders et al., 2021; Fuhs et al., 2013). Our researcher report based on observations of toddlers' self-regulation during the testing sessions may be less biased by parental perceptions of their children's behavior, resulting in stronger associations with performance on math assessments, parent-reported language skills, and family SES. Alternatively, the associations between self-regulation observed during the assessment battery could reflect situational confounds. For example, a child who was particularly off-task may be rated as lower on attention and inhibition by the researchers would be expected to score lower on other assessments as a result of this state-level inattentiveness. However, this possibility would not explain why associations between SES and self-regulation were stronger among researcher-reported rather than parent-reported measures or why only researcher-reported self-regulation measures related to parent-reported vocabulary. Unfortunately, we are unable to tease apart these possible explanations with these cross-sectional, correlational data, but the present findings underscore the need for more multimethod studies of self-regulation given the differences in how measures operated.

One limitation of both self-regulation measures, however, is that they rely on an adult interpreting and rating a child's behavior to assess self-regulation. In contrast, several direct assessments or behavioral observations of toddlers' ability to self-regulate have also been developed. For example, one commonly reported measure is a multi-task battery as described by Kochanska and colleagues (2000), in which effortful control skills (i.e., delaying, modulation of motor activity and voice, suppressing-initiating activity to signal, and effortful attention) are

assessed in the context of "short games" that children play with a trained researcher. Other observational measures of self-regulation assess children's attention through observing time spent interacting with an engaging toy (often referred to as sustained attention; e.g., Choudhury & Gorman, 2000) or persisting with a difficult task, such as an unsolvable puzzle (e.g., Schumacher et al., 2017; Smiley & Dweck, 1994). Measures targeting toddlers' early executive functions in particular have also been developed, including A-not-B tasks and delay tasks that require children to inhibit learned or desired behaviors (see Morasch & Bell, 2011). These behavioral measures are intended to capture similar aspects of self-regulation as adult-reported measures without the bias of adult-report measures, but it is notable that these measures may reflect social and behavioral regulation, more in line with factors such as effortful control or temperament, as opposed to more cognitive aspects of self-regulation such as executive functioning (see Liew, 2012, for discussion). Future research incorporating these well-validated yet somewhat distinct measures with the model of self-regulation shown here would provide broader information on how early self-regulatory capacities relate to SES as well as pre-academic skills.

4.2. Direct and Indirect Effects of SES on Math and Language Skills

Consistent with past research with older children (Evans & Rosenbaum, 2008; Finders et al., 2021; Sektnan et al., 2010), indirect effects of SES on pre-academic skills were observed. We extend this work by demonstrating that these pathways emerge as early as two to three years of age, when children's self-regulatory skills are undergoing considerable refinement. In particular, the finding that higher SES children are already at an advantage in the development of self-regulation during the toddler years highlights the need for early interventions for lower SES children. Many programs have been designed and implemented to help support children's

developing self-regulatory skills in the preschool and kindergarten classroom (Pandey et al., 2018; Schmitt et al., 2015; Ursache et al., 2012). Given that disparities in self-regulation may already be present prior to the start of these interventions, future work should explore the extent to which earlier intervention may be feasible.

Although we found differences in the self-regulatory skills of low- and high-SES toddlers, no bivariate association was evident between SES and early math skills, despite evidence that SES gaps in children's math skills are quite sizeable by school entry (Cheadle, 2008; Duncan & Magnuson, 2011; Jordan et al., 2007; Starkey et al., 2004). As such, it is possible that these disparities emerge later in development (but see Halle et al., 2009), yet more research is needed to understand why. For example, SES differences may be small and difficult to detect statistically in smaller samples during toddlerhood, but these differences may snowball over time as math skills start to build more on one another. Alternatively, the later emergence of SES disparities in math could be due to increases in SES differences in environmental input (e.g., math activities or talk about numbers) such that SES differences in parents' support for their toddlers are less pronounced than for older children. Some evidence suggests that higher SES parents may use more number talk with their young children but that parents' number talk to their children in general increases during the infant and toddler years (Levine et al., 2010), and so it is possible that SES differences in number talk may be relatively small during the first few years of life if number talk is infrequent for all families. However, little is known about what activities at home might promote toddlers' math learning in particular. It is also possible that these differences might be more easily detectable in a larger sample with a larger proportion of low-SES families.

In contrast, SES differences in expressive vocabulary size were present even among this sample of two- to three-year-old children, both in the bivariate correlations as well as adjusted effects controlling for self-regulation and covariates. These findings are consistent with past research demonstrating that differences in the expressive and receptive language skills of young children from low- and high-SES backgrounds can be seen as early as 18 months (e.g., Fernald, Marchman, & Weisleder, 2013). This earlier emergence of differences in language skills may be attributable to the differences in measurement (i.e., parental report for vocabulary vs direct assessments for math), which should be corroborated with more measures in similar modalities in the future. Alternatively, earlier SES differences in toddlers' vocabulary compared to math may be due to differences in the environmental inputs that support language skills and vocabulary in particular during the toddler years, such as shared book-reading and rich linguistic input (Pan et al., 2005; Rowe, 2012; Schmitt et al., 2011), which have been shown to differ by SES (Attig & Weinert, 2020; Linberg et al., 2020; Rowe, 2008). Although our focus in the current study was on children's own self-regulation as a mechanism through which SES might relate to pre-academic skills, the residual associations between SES and vocabulary suggest that other, unmeasured factors such as the home environment may contribute to some of these SES differences.

4.3. Limitations and Conclusions

Several limitations should be noted when considering the present findings. First, all data were collected at a single time point, and so although we have estimated models with the assumption that SES shapes toddlers' self-regulation and self-regulation in turn promotes pre-academic skills, we are unable to establish causal or directional associations in this study. Additionally, as noted previously (section 4.1), some reports of children's observed self-

regulation was drawn from the same testing sessions as direct assessments of children's math skills, and so it is possible that these reported associations may be inflated by situational confounds and reflective of children's performance on that day rather than their competence (e.g., if a child was not particularly attentive during the testing session, resulting in lower self-regulation ratings and performance on assessments). However, reports of self-regulation from a second day of testing were also included in this composite, somewhat offsetting this potential confound. Additionally, there may be further distinctions in these factors of self-regulation that could not be detected here, which should be examined in future work.

We also note that although families reported a wide range of incomes, there was a restriction of range of parent education, such that the majority of households had at least one parent with a bachelor's degree. However, the overall SES composite demonstrated substantial variability, as well as concurrent validity in associations with age 2 self-regulation ratings and predictive validity in associations with age 3 vocabulary skills. In future research, inclusion of more families with lower levels of educational attainment or household income would allow for more generalizability in these findings and more robustly detect associations between SES and related constructs in this study. This increased variability would also help to differentiate associations with income and education separately, as the approach used in the present analyses of combining these theoretically distinct factors is less than ideal (see Diemer, et al., 2013). These data were also collected during a unique time, specifically during a global pandemic in which families likely experienced major changes in their daily lives and mental health. The pandemic also placed constraints on the study, such as online administration of tasks and observations of child behavior and the inability to recruit families in person at preschools and community events, all of which should be considered when interpreting these findings.

Furthermore, we expect that rates of missing data due to children's unwillingness to complete assessments, particularly for the counting task that required a verbal response from children, were elevated in this work due to the reliance on virtual data collection methods.

Relations between self-regulation and pre-academic skills, particularly skills related to math, may vary depending on conceptual and methodological aspects of self-regulation during toddlerhood, as we demonstrate in our findings. This has important implications for practice and subsequent research. Specifically, not only can the observation of these relations vary depending on the specific components of self-regulation being measured, but they can also vary depending on the actual measurement sources for these components. This may be particularly relevant in the context of intervention work concentrating on periods of early childhood. We found that parent reported self-regulation was not robustly related to SES and children's pre-academic skills as were assessor ratings, which may be particularly salient in the context of designing and assessing interventions.

In general, our findings demonstrate that the self-regulatory skills observed by parents and by researchers reflect distinct behaviors, underscoring the need to obtain multi-method measures of self-regulation in these early years. Further, we show that parent reported self-regulation is not robustly related to children's pre-academic skills and demonstrate the need for alternative measures of self-regulation. We add to the growing work documenting SES disparities in children's self-regulation among children as young as two years of age and show that these early SES differences in self-regulation are unique to researcher-rated behaviors. Finally, associations between self-regulation and children's early math and language skills demonstrate that these disparities in early self-regulation may have implications for later

academic skill development given the associations seen here with toddlers' concurrent pre-academic skills.

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Table 1

Descriptive statistics and sample sizes for key study variables

Variable	N	Mean	SD
Sample Demographics			
Child Age (in Years)	153	2.66	0.21
Parent Age (in Years)	153	34.49	4.69
Adults in the Home	157	1.94	0.38
Children in the Home	157	1.98	0.91
Parent is Married	157	80%	
Parent Race	153		
White, Non-Hispanic		76%	
Black		12%	
Asian		2%	
Hispanic/Latino		3%	
Other or Multiracial		3%	
Prefer not to answer		3%	
SES Variables			
Income (in 10,000's)	156	10.07	5.83
Income-to-Needs Ratio	156	4.12	2.58
Parent Education	156		
Less than High School		1%	
High School Diploma/GED		8%	
Vocational/Technical Program		3%	
Some College		8%	
Associates' Degree		4%	
Bachelors' Degree		23%	
Graduate Degree		53%	
Self-Regulation			
ECBQ: Attentional Focusing	150	5.07	0.77
ECBQ: Attentional Shifting	148	4.07	0.76
ECBQ: Inhibitory Control	149	4.03	0.89
PSRA: Attention Day 1	149	2.10	0.88
PSRA: Inhibitory Control Day 1	149	2.01	0.55
PSRA: Attention Day 2	145	2.21	0.91
PSRA: Inhibitory Control Day 2	145	2.09	0.51
Pre-Academic Skills			
Give-N	130	1.95	1.54
Point-To-X	134	0.64	0.17
Counting	112	8.65	6.28
Vocabulary	141	89.94	38.10

Table 2

Correlations for all study variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. ECBQ: Attentional Focusing	1											
2. ECBQ: Attentional Shifting	.29***	1										
3. ECBQ: Inhibitory Control	.29***	.52***	1									
4. PSRA: Attention Day 1	.21*	0.11	0.34	1								
5. PSRA: Inhibition Day 1	.26**	.20*	0.35	.78***	1							
6. PSRA: Attention Day 2	.26**	.17*	.36***	.75***	.71***	1						
7. PSRA: Inhibition Day 2	.25**	.18*	.37***	.71***	.72***	.86***	1					
8. Give-N	.31***	.17†	.20*	.34***	.29***	.33***	.31***	1				
9. Point-To-X	.16†	0.13	.20*	.16†	.18*	.16†	.21*	.61***	1			
10. Counting	.28**	0.15	0.23	.33***	.27**	.35***	.30**	.50***	0.51	1		
11. Vocabulary	.32***	.16t	.18*	.43***	.32***	.43***	.40***	.31***	0.26	0.4	1	
12. SES Composite	0.12	0.07	0.13	.17*	.16†	.15†	0.13	0.09	0.11	0.12	.37***	1
13. Child Age (in Years)	.15†	0.04	0.05	0.06	0.02	0.07	0.07	.30***	.28**	0.12	.16t	0.05

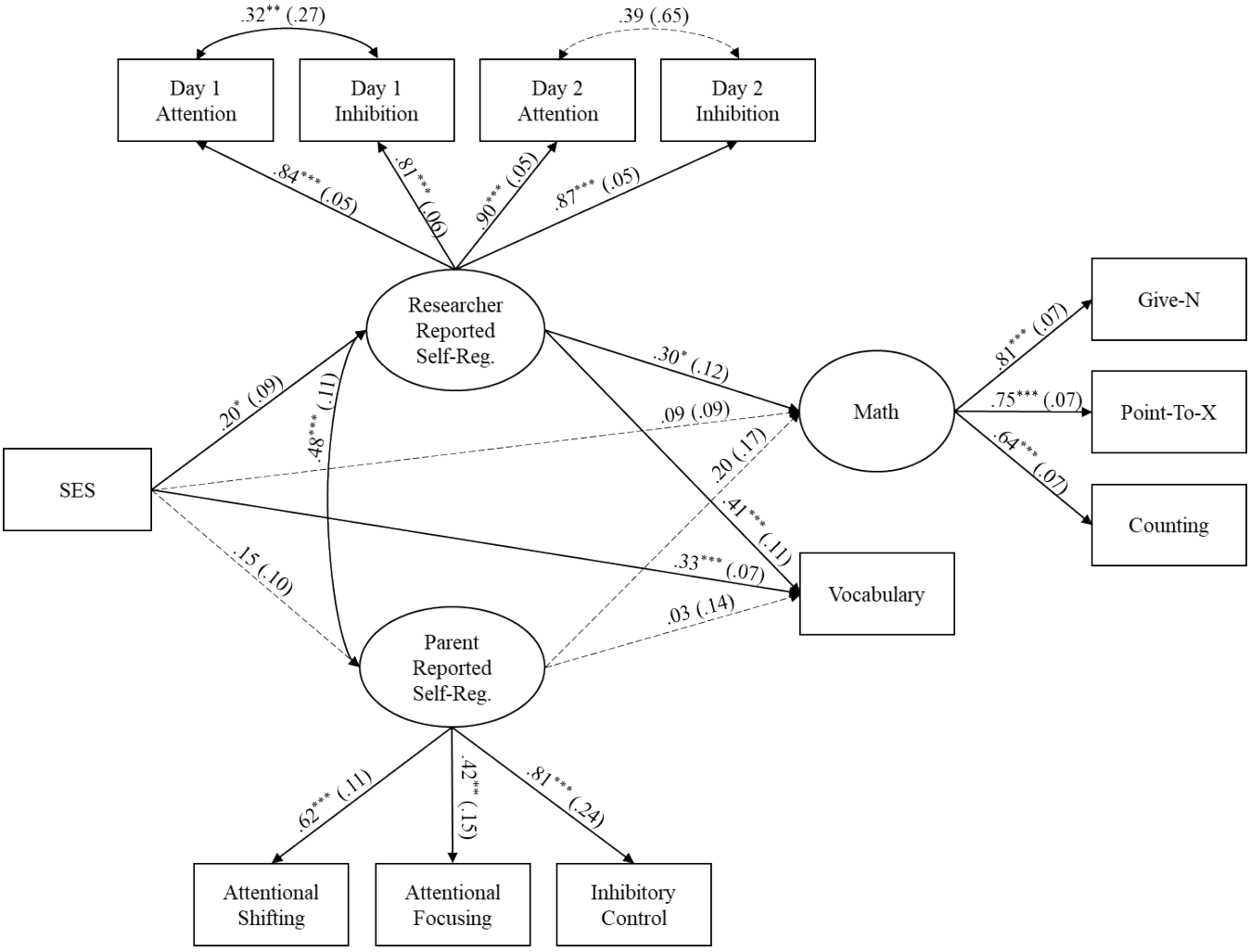

Figure 1. Standardized estimates and their standard errors from the structural model of SES, self-regulation (self-reg.), and pre-academic skills. SES was modeled as a single indicator latent variable but is shown as an observed variable for clarity. This model also included controls for child age and parent race/ethnicity, which are not shown in the Figure. Significant pathways are shown in solid bold lines, with non-significant pathways shown in dashed lines.

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

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