## Title

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# Longitudinal Relations Between Self-Regulatory Skills and Mathematics Achievement in Early Elementary School Children from Chinese American Immigrant Families

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## Abstract

Drawing from two waves (approximately 1.5-2.5 years apart) of longitudinal data, the current study investigated the bidirectional associations between self-regulatory skills and mathematics achievement among a socioeconomically diverse sample of school-aged Chinese American children from immigrant families ($N$ = 258, 48.1% girls, age = 5.8-9.1 years, 1st to 3rd grades at Wave 1). Children's self-regulatory skills were assessed with task-based measures of attention focusing, inhibitory control, behavioral persistence, and comprehensive executive function, as well as parent- and teacher- reported effortful control. Multiple regressions showed that behavioral persistence and parent-reported effortful control positively predicted math achievement over time. Math achievement positively predicted comprehensive executive function over time. These effects were found controlling for child age, sex, generation status, family socioeconomic status, parents' cultural orientations, and prior levels of math achievement or self-regulation. The prospective relation of math achievement predicting comprehensive executive function remained significant after a false discovery rate correction.

### Keywords

self-regulatory skills; executive function; effortful control; math achievement; Chinese American children; immigrant families

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Poor academic achievement is associated with crippling consequences including lowered occupational attainment, heightened psychopathology, and increased substance use (Henry et al., 2012; Masten et al., 2005; Mirowsky & Ross, 2003). While self-regulatory processes facilitating goal-oriented thought and behavior (Karoly, 1993) are often studied as key predictors of academic achievement (mathematics in particular), evidence suggests that self-regulation and achievement are bidirectionally related (Clements et al., 2016; Fuhs et al., 2014; Mägi et al., 2016; Sánchez-Pérez et al., 2018; Schmitt et al., 2017). Single-method

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studies of self-regulatory skills remain common despite calls for better methodological integration, leading to what has been termed “measurement mayhem” (Morrison & Grammer, 2016). Furthermore, the links between math achievement and self-regulatory skills are understudied among Chinese American children in immigrant families. This is notable given the inconsistency with which these links have been found among children in China compared to their Western counterparts (e.g., Fung et al., 2020; Lan et al., 2011). The inconsistent findings highlight the need to better understand whether culture-related processes may affect the link between self-regulation and math achievement. Therefore, multi-modal study of the relations between self-regulation and math achievement in Chinese American children from immigrant families attending U.S. schools enables us to: 1) test the generalizability of developmental theory on self-regulation, 2) investigate whether and how the roles of self-regulation in math development vary across contexts, and 3) clarify the best self-regulatory predictors of math achievement beyond traditional methodological boundaries.

The present study examined the bidirectional relations between self-regulation and math achievement in a longitudinal study of Chinese American school-age children from immigrant families. We used multiple task-based and questionnaire measures of self-regulatory skills. Using two waves of data, we tested whether self-regulation and math achievement predicted one another controlling for prior levels as well as theoretically supported demographic/sociocultural characteristics (child age, sex, generation status, family socioeconomic status/SES, and parent cultural orientations).

## Self-Regulation

Self-regulatory processes allow individuals to guide their goal-oriented cognition and behavior across time and contextual circumstances (Karoly, 1993). Executive function (EF) and effortful control (EC) constitute two major self-regulatory constructs in research on children and adolescents. These two constructs have been largely studied separately as they emerged from distinct disciplinary literatures, which has obscured potential methodology-associated differential contributions to outcomes such as mathematics achievement (Sulik et al., 2016; Zhou et al., 2012).

EF is typically conceptualized as a unitary construct composed of multiple interrelated cognitive processes (Garon et al., 2008). Three commonly studied EF processes include working memory, inhibitory control, and cognitive flexibility (e.g., Diamond, 2013). Working memory is the ability to actively hold information in mind and manipulate it (Baddeley, 1986; Gathercole et al., 2006). Inhibitory control is the ability to inhibit prepotent responses (Miyake et al., 2000). Cognitive flexibility is the capacity to modify cognition and behavior in the face of changing contextual demands (Davidson et al., 2006). Other cognitive processes less commonly classified as EFs include attention focusing (alternately termed sustained attention), which refers to the ability to sustain attention on pertinent contextual stimuli (Garon et al., 2008). Attention focusing is occasionally considered an EF (e.g., Jacob & Parkinson, 2015), but is more often considered a component of EC. EC is an aspect of temperament associated with the self-regulation of behavior (Chen et al., 2015; Zorza et al., 2019). Like EF, EC is thought to encompass multiple interrelated components including attention focusing, inhibitory control, attention shifting (largely akin to cognitive flexibility), conflict resolution, error detection/correction, and action planning (Rothbart & Bates, 2006).

Despite the conceptual overlap between EF and EC, the two constructs have historically been studied using different assessment methods (Zhou et al., 2012). EF skills are typically measured using cognitive tasks administered in the laboratory, whereas EC is commonly measured by parent or teacher questionnaire ratings of children's everyday behavior (Diamond, 2013). Empirical studies have reported modest associations between task-based and questionnaire measures of self-regulation (e.g., Soto et al., 2020), which suggests the methodological difference is empirically meaningful. Task-based and questionnaire measures of self-regulation may map onto separate theorized mechanisms through which self-regulatory processes are involved in math development.

## The Role of Self-Regulatory Skills in Math

### Self-Regulation During Mathematical Operations and Task-Based Measurement

Self-regulatory skills are critical for the development of mathematical abilities because multiple self-regulatory skills are employed when children attempt to solve math problems (see Best et al., 2009 and Clements et al., 2016 for reviews). Specifically, children must sustain their attention on pertinent information (attention focusing) and hold it in mind while solving the broader math problem (working memory). Inhibitory control is employed when children need to ignore salient yet extraneous information and inhibit unproductive strategies or incorrect responses. Clements and colleagues (2016) pose the following word problem to illustrate, "There were six birds in a tree. Three birds already flew away. How many birds were there from the start?" Attending to the birds flying away may inappropriately lead to use of subtraction, which must be inhibited as a strategy to correctly solve the problem. Cognitive flexibility is required to switch between solution strategies and attend to multiple aspects of a math problem (e.g., reconsidering the numerical entity of 2/3 as 4/6 when attempting to add it to 5/6).

Lab-based cognitive tasks and behavioral measures of self-regulation are well-suited for illustrating the direct associations between self-regulation and math achievement (particularly when measured by achievement tests instead of school grades). This is because they capture relatively pure information about one's self-regulatory capacities in an optimal setting (Gerst et al., 2017; Toplak et al., 2013). Indeed, researchers have found positive associations between performance on math achievement tests and lab-based cognitive measures of attention focusing (e.g., Anobile et al., 2013; Commodari & Di Blasi, 2014; Dulaney et al., 2015) and inhibitory control (e.g., Agostino et al., 2010; Blair & Razza, 2007; Fuhs et al., 2015; Monette et al., 2011; Verdine et al., 2014) in preschool- to school-aged children.

Behavioral measures of self-regulation tapping multiple self-regulatory skills have likewise shown positive associations with math achievement. For instance, the Head-to-Toes Task is theorized to tap attention, inhibition, and working memory (Cameron Ponitz et al., 2008). The Head-Toes-Knees-Shoulders Task (McClelland et al., 2014) resembles the Head-to-Toes

Task but also captures cognitive flexibility and more heavily taps working memory due to an increased number of rule sets. Performance on both tasks has been shown to positively predict subsequent math achievement during preschool, kindergarten, and elementary school (Hernández et al., 2018; McClelland et al., 2007; McClelland et al., 2014; von Suchodoletz & Gunzenhauser, 2013). Eisenberg and colleagues (2001, 2005) developed a measure of behavioral persistence using a mildly frustrating problem-solving task (puzzle box task), which is theorized to tap both attention focusing and inhibitory control (Zhou et al., 2007). Prior analyses of Wave 1 data from the present longitudinal study found positive, concurrent associations between the behavioral persistence measure and math achievement at ages 6 to 9 years (Chen et al., 2015). Although behavioral persistence on the puzzle box task has not otherwise been studied in relation to math achievement, another study assessed children's persistence using a series of cognitive tasks at age 3 and found it to predict math achievement at age 5 (Martin et al., 2013).

### Broader Behavioral Regulation and Questionnaire-Based Measurement

Self-regulatory skills can also enhance math proficiency by promoting children's appropriate classwork/homework-related behavior and adaptive interpersonal behaviors in classrooms. Specifically, self-regulatory skills enable children to stick to and complete academic tasks despite fatigue or distraction and promote their internalization of math instruction (Blair & Razza, 2007; Clements et al., 2016; Neuenschwander et al., 2012). Moreover, self-regulation can foster students' adaptive interpersonal behaviors, strengthening their relationships with peers and teachers (Wentzel & Ramani, 2016; Zorza et al., 2019). This, in turn, may make others more effective resources for academic help and promote students' academic motivation and school attachment. Questionnaire ratings of everyday behavior are suitable for investigating these pathways as they capture observable deployment of self-regulatory skills across contexts, affective states, and in service of both academic and interpersonal goals (Gerst et al., 2017; Zorza et al., 2019). Indeed, there is evidence of positive relations between questionnaire measures of self-regulation (including ones tapping the subcomponents assessed by the present study's rating scales) and math achievement during the pre-/elementary school periods (e.g., Blair & Razza, 2007; Blair et al., 2015). Additionally, children's social behavior and peer status have been found to mediate the positive associations between questionnaire ratings of self-regulation and academic achievement (Zorza et al., 2013, 2019).

## Bidirectional Relations Between Self-Regulation and Math Achievement

While self-regulatory skills are theorized to shape math development, math achievement is also theorized to shape the development of self-regulation. As with exercise and muscle development, using self-regulatory skills in daily activities is thought to strengthen one's self-regulatory "musculature" (Peng & Kievit, 2020). Specifically, children's self-regulatory musculature can be exercised through engaging in academic tasks (including math-related learning exercises; Clements et al., 2016; Evans & Stanovich, 2013; Peng et al., 2018). On the other hand, children who encounter academic difficulty due to lower math proficiency may become less engaged in their learning (Hughes et al., 2008). This may lead to less time and effort pursuing academic tasks, resulting in less self-regulatory exercise. Consistent with theory, Pagani and colleagues (2012) found that early math skills predicted children's classroom engagement.

Increasing evidence has shown both prospective links from math achievement to self-regulatory skills as well as bidirectional relations. Swanson and colleagues (2014), for example, found that kindergarten math positively predicted parent-reported EC in first grade (Rothbart et al., 2001). Likewise, DeFlorio et al. (2019) reported that mathematical knowledge positively predicted preschoolers' subsequent persistence on a frustration task. They also observed bidirectional associations between math knowledge and performance on inhibitory control tasks (DeFlorio et al., 2019). In another longitudinal study following children from preschool through kindergarten, Son et al. (2019) found bidirectional relations between math achievement and task-based inhibitory control. Kim et al. (2018) found bidirectional relations between math achievement and task-based attention focusing across kindergarten. Bidirectional associations have also been observed between math achievement and Head-to-Toes Task performance (McClelland et al., 2007) as well as Head-Toes-Knees-Shoulders Task performance (Cameron et al., 2019; Hernández et al., 2018; ten Braak et al., 2019) among children in preschool, kindergarten, and elementary school. Several studies utilizing latent or composite EF variables derived from performance on tasks tapping working memory, inhibitory control, and cognitive flexibility have shown bidirectional relations with math achievement in the preschool period up through early elementary school (Fuhs et al., 2014; McKinnon & Blair, 2019; Nesbitt et al., 2019; Schmitt et al., 2017; Welsh et al., 2010).

## Links Between Self-Regulation and Math Achievement Among Chinese American Children

Because prior research on self-regulation and math development has rarely focused on either immigrant or Asian American communities, the generalizability of these relations among Chinese American children in immigrant families remains to be tested. The Chinese American community has one of the highest growth rates of any ethnic group in the U.S. (Zong & Batalova, 2017). Cross-cultural studies of children in China and the U.S. have documented differences in both self-regulation (Lan et al., 2011; Sabbagh et al., 2006) and mathematics proficiency (Cai, 1995; Geary et al., 1993). Within the U.S., a recent meta-analysis found EF differences between Asian Americans and other racial/ethnic groups and highlighted the "dramatic underrepresentation" of Asian Americans within published research as a major study limitation (Rea-Sandin et al., 2021). Most notably, investigators have found that relations between math and self-regulatory skills among American children differ from those among Chinese children. In contrast to the bulk of the extant literature, findings from Chinese samples largely have not shown significant relations between self-regulatory skills and math achievement. For example, Lan et al. (2011) noted that preschool Head-Toes-Knees-Shoulders Task performance and calculation proficiency were uniquely associated among American children but not among Chinese children. Fung and colleagues (2020) observed among Chinese children in Hong Kong that neither self-regulatory skills (measured using an aggregate variable composed of performance on multiple EF tasks) nor math achievement in kindergarten predicted the other construct in first grade.

Dissimilar math – self-regulation associations have been attributed to English-Chinese language differences and differing degrees of exposure to mathematics content in early childhood (e.g., Wei et al., 2018). Regarding language, working memory is theorized to be less important for math achievement in Chinese children than Western children because Chinese dialects have a comparatively transparent number naming system and shorter digit names, which lessen the working memory load of performing mathematical operations in Chinese (e.g., Georgiou et al., 2020). Inhibition is also theorized to relate to math achievement differently among school-aged Chinese children because they are taught addition, subtraction, and multiplication respectively earlier in school compared to children in North America (Georgiou et al., 2020; Miller et al., 2005; Wei et al., 2018; Zhou et al., 2011).

Chinese children also receive greater exposure to mathematical content at home with cross-cultural research finding higher parental involvement in math learning among Chinese parents than American parents (e.g., Pan et al., 2006). Chinese American children similarly appear to benefit from greater at-home math exposure in comparison to European American children (e.g., Huntsinger & Jose, 2009; Huntsinger et al., 2000). Children from Chinese American immigrant families frequently participate in parent-initiated afterschool, extracurricular academic activities and are subject to high parental academic expectations (Gibbs et al., 2017; Zhou & Lee, 2014). Greater math exposure and practice can facilitate greater automaticity, reducing the need for inhibitory control because answers can be directly retrieved from long-term memory (Evans & Stanovich, 2013; Wei et al., 2018). Indeed, Chinese children develop calculation automaticity earlier than children in Western countries (e.g., Cui et al., 2017; Geary et al., 1996; Rodic et al., 2015). Therefore, inhibitory control may be less important for school-aged Chinese (and potentially Chinese American) children's math achievement, which might explain Fung and colleagues' null findings (2020). Paradoxically, Georgiou et al. (2020) contend automatized calculation requires increased inhibitory control due to interference from other automatized operations (e.g., retrieval of 4x4 interfering with solving 4+4). Regardless, there is agreement that culture-related automaticity might influence inhibitory control – math associations.

In sum, examining associations between self-regulation and math achievement longitudinally among Chinese American children from immigrant families who are attending U.S. schools could help shed light on the roles of the school and home contexts in math development. Exploring these associations with various measures of self-regulation could help elucidate how and under what conditions self-regulation and math development relate to one another.

## The Present Study

Drawing from a sample of Chinese American children from immigrant families, the study had two aims. Aim 1 was to examine prospective associations from self-regulation to math. We hypothesized that all self-regulatory measures would positively predict math achievement. Aim 2 was to examine prospective relations from math achievement to self-regulation. We hypothesized that math achievement would positively predict each self-regulatory measure. We incorporated multiple measures of self-regulation, including both task-based and questionnaire measures, measures that tap individual EF/EC skills (e.g., inhibitory control, attention focusing), and comprehensive measures of EF and EC.

We expected to observe an overall similar pattern of associations in our sample as compared to the pattern found in predominantly Western samples. This was because the participating children in the present sample attended American schools and completed the assessments primarily in English. Using two waves of data, each hypothesized association was tested in a separate regression model controlling for prior levels of self-regulation or math achievement as well as the potentially confounding factors of child generation status, sex, age, SES, and parent cultural orientation. These factors were selected as potential covariates given previous findings. Prior analyses of data drawn from the present sample showed child generational, sex, age, family SES, and parent cultural orientation differences in both child self-regulatory skills and academic achievement (Chen et al., 2015; Mauer et al., 2021).

## Method

### Participants

The sample consisted of 258 Chinese American children (48.1% girls, mean age = 7.4 years at Wave 1 or W1, age range = 5.8-9.1 years), their parents, and teachers who participated in a longitudinal study of academic development and psychological adjustment in the San Francisco Bay Area (Chen et al., 2014, 2015; Mauer et al., 2021). Data were collected in two waves. At W1 (data collected between December 2007 and July 2009), the children were in first (48.8%), second (50.0%), or third (1.2%) grades. Almost all (94.5%) were enrolled in public schools. Most children (76.4%) were born in the U.S. and had one or more foreign-born parents; the remainder (23.6%) were foreign-born themselves. Most parents were born in mainland China (77.3% of mothers, 68.8% of fathers), Hong Kong (9.0% of mothers, 8.6% of fathers), or Taiwan (2.7% of mothers, 3.1% of fathers). A small percentage of parents (1.2% of mothers, 4.3% of fathers) was born in the United States. On average, mothers and fathers had lived in the U.S. for 11.13 years (range = 0.5-30 years, $SD = 6.84$) and 15.10 years (range = 0.0-50 years, $SD = 9.74$) respectively. Children mostly resided in two-parent households (91.4%); a small proportion (8.6%) came from households in which parents were separated, divorced, single, or widowed. Participating families' per capita income in the past year ranged from \$625 to \$50,000 ($M$ = \$11,609, $SD$ = \$8309); 57% of children were from low-income families based on their eligibility for free or reduced-price school lunch.

At Wave 2 (W2; data collected between November 2009 and May 2011), 93% of the sample was retained. The average time interval between W1 and W2 was 22.5 months ($SD = 3.1$). All children chose to complete their W2 assessments in English. Children at W2 were in second (2.9%), third (45.6%), fourth (47.7%), or fifth grades (3.8%). Fifty-nine percent of children were from low-income families based on their eligibility for free or reduced-price school lunch.

Attrition analyses were conducted to compare the children for whom there were self-regulatory and math achievement data at both waves ($N = 241$) with those who had W1 data only ($N = 17$). Independent sample $t$-tests were computed to compare the two groups on continuous variables (child age, family SES, parent American cultural orientation, parent Chinese cultural orientation, self-regulatory variables, and math achievement), *t*s (*df*s = 213 to 255) = −1.71 to 0.65, *p*s = 0.09 to 0.96, *d*s = 0.14 to 15.82. Pearson chi-square statistic was used to compare the two groups on categorical variables (child sex and generation status), $\chi^2$ ($df = 1$) = 0.01 and 0.00, *p*s = 0.93 and 0.99, Φs = −0.01 and −0.00. Thus, children for whom data were obtained at both waves and only the first wave did not significantly differ on any of the self-regulation or math variables or potentially confounding demographic and sociocultural factors (child age, sex, generation status, family SES, and parent cultural orientation).

## Procedures

The sample was recruited through multiple strategies, including recruiting at elementary schools with substantial proportions of Asian American students, recruiting at Chinatown shopping centers, Asian grocery stores, and Asian American community events, as well as seeking referrals from Asian American organizations. Parents interested in participating completed a contact sheet and were later contacted by a bilingual phone screener. The eligibility criteria included: (a) the child was in first, second, or third grade, (b) the child lived with at least one biological parent, (c) both biological parents self-identified as ethnically Chinese, (d) the child or at least one parent had immigrated to the U.S. (i.e., the child was a first- or second-generation immigrant), and (e) both the participating parent and child could speak or understand English, Cantonese, or Mandarin. Three hundred eighty parents filled out a contact sheet, and 353 of those parents completed phone screens. Of the 291 children who met the eligibility criteria, 258 children completed the W1 assessment.

The Institutional Review Board at the University of California, Berkeley approved all research procedures (Protocol title: “The risk and protective factors for mental health adjustment in 1st and 2nd generation Chinese American immigrant children”). At both waves, a 2.5-hour laboratory assessment was administered to the child and one parent. The laboratory assessment included parent questionnaires, child achievement and neuropsychological tests, and parent-child interaction tasks. Because mothers were asked to participate in the lab assessment whenever possible, most participating parents were mothers (81.8% at W1, 79.9% at W2). Written consent and assent materials were made available to participants in English, simplified Chinese, and traditional Chinese.

The assessments were administered in the parents’ and children’s preferred languages. Most parents (83.7% at W1 and 82.6% at W2) completed the questionnaires in Chinese. Most children (93% at W1 and 100% at W2) completed their questionnaires in English. Children’s classroom teachers completed a teacher questionnaire by mail after the laboratory assessment. All teachers completed W1 and W2 questionnaires in English. For each child, the teacher who filled out a questionnaire at W1 differed from the teacher who completed one at W2. Most teachers (81.2% at W1 and 79.2% at W2) completed questionnaire packets for a single student, with the remainder completing packets for up to 10 students at W1 and 11 students at W2. At W1, 138 teachers completed questionnaires and 154 did so at W2. Parents and teachers received payment and children received small prizes for their participation.

### Measures

The present study used data collected from child self-regulatory and achievement tasks as well as items from parent and teacher questionnaires. Measures not previously used with Chinese-speaking samples (i.e., the family demographics questionnaire, the self-regulatory tasks, and the math achievement tests) were translated, back-translated, and piloted in accordance with conventions outlined by Knight et al. (2009). Because some children received verbal instructions for child assessment tasks in Chinese at Wave 1 (12.4%), independent sample *t*-tests were computed to compare their performance on each task to that of children who received all task instructions in English, *t*s (*df*s = 204 to 215) = −1.23 to 0.38, *p*s = 0.20 to 0.88, *d*s = 0.07 to 15.50. No differences were found, suggesting child task language did not influence performance. All children received the verbal instructions for child assessment tasks in English at W2.

**Task-Based Self-Regulation (W1 & W2)—**A lab-designed, computerized Go/No-Go task assessed attention focusing (sustained attention) and inhibitory control (Eriksen & Eriksen, 1974). Children were instructed to press a button only in response to the target stimulus and were subsequently presented with a sequence of images. Low rates of omission errors (i.e., not responding to the target stimulus) and commission errors (i.e., responding to non-target stimuli) are used as measures of attention focusing and inhibitory control respectively (Barkley, 1991; Halperin et al., 1988). Each stimulus was presented for 2 s. Following 30 practice trials during which correctional feedback was provided, children were presented with 200 trials containing the target stimulus and 50 non-target trials. Data from a W1 subsample were used to analyze task reliability because trial-level data were unavailable for the full sample. Given Cronbach's alpha's propensity for underestimating internal consistency, Guttman's lambda 4 was calculated to evaluate split-half reliability for the computerized tasks (Sijtsma, 2009). Guttman's lambda 4 reliability coefficient for the Go/No-Go task was 0.81.

A puzzle box task during which children attempted to assemble a wooden puzzle in a box without looking inside the box was used to assess behavioral persistence (Eisenberg et al., 2001, 2005). Children were videotaped using a visible camera and left alone to complete the task for up to 5 minutes. Participants could easily cheat by peering inside the box. The number of seconds spent on-task without cheating was coded independently by two research assistants. Behavioral persistence was computed as time spent working on the puzzle without cheating divided by the duration of the task (see Eisenberg et al., 2001). The intra-class correlations between main and reliability coders on behavioral persistence were 0.95 at W1 and 0.98 at W2. This task has shown convergent validity with other self-regulatory measures in longitudinal research on European American children (Eisenberg et al., 2005) and prior analyses using data drawn from the present sample of Chinese American children (Chen et al., 2014, 2015).

A complex rule use computer task from Baym et al. (2008) jointly tapping working memory, inhibitory control, and cognitive flexibility was used to assess comprehensive EF. Versions of this task have been used in multiple studies with school-aged children (Church et al., 2017; Tharp et al., 2015; Wendelken et al., 2012). During the task, a sequence of on-screen stimuli (images from an animated film) was presented to children, who were taught to respond by pressing one of two buttons depending on a given image's associated rule cue of Color (red or blue) or Direction (left or right). The rule cue for any given image either differed from that associated with the previous image (Switch trial) or remained the same (Repeat trial). Successful task performance required dynamic rule implementation as the visual features and relevant rule cue for each trial changed at random intervals. During Direction trials, participants were asked to press either a left or right button based on the on-screen image's direction. During Color trials, participants were required to press either a left or right button depending on the on-screen image's color.

During each trial, the pertinent rule cue ("Direction" or "Color") was first presented for 2300 ms followed by the stimulus for 1500 ms. Some trials included images that would require differing responses depending on the associated rule cue (Incongruent trial). Other trials included images that would require the same button press regardless of rule cue (Congruent trial). Children's accuracy percentage on the Incongruent-Switch trials was used as a broad indicator of EF since these trials required working memory (keeping two rules in mind), cognitive flexibility (switching between the rules), and inhibitory control (overriding responses based on the currently irrelevant stimulus feature). This task has also shown convergent validity with other self-regulatory measures in prior analyses of data from the present sample (Chen et al., 2014, 2015; Mauer et al., 2021). Split-half reliability (computed as Guttman's lambda 4 reliability coefficient) for the W1 subsample Incongruent-Switch trials was 0.81.

**Self-Regulation Questionnaires (W1 & W2)—**Parents and teachers completed the attention focusing (12 items) and inhibitory control (12 items for parents, 10 items for teachers) subscales of the Children's Behavior Questionnaire (Rothbart et al., 2001). Respondents rated each item on a 7-point scale (1 = *extremely untrue*, 7 = *extremely true*). Two items were removed from the parent-reported attention focusing subscale, and one item was removed from the teacher-reported attention focusing subscale due to negative item-total correlations. Cronbach's alpha for the parent-report subscales was 0.73 (W1) and 0.80 (W2) for attention focusing and 0.71 (W1) and 0.72 (W2) for inhibitory control. For teacher-report subscales, Cronbach's alpha was 0.90 (W1) and 0.90 (W2) for attention focusing and 0.80 (W1) and 0.81 (W2) for inhibitory control. Congruent with the theoretical account of attention focusing and inhibitory control as related subcomponents of EC (Rothbart & Bates, 2006), the within-reporter attention focusing and inhibitory control subscales were positively correlated (parent-report $r$s = 0.48 at W1 and 0.64 at W2, $p$s < .001; teacher-report $r$s = 0.43 at W1 and 0.73 at W2, $p$s < .001). At both waves, the item scores across the attention focusing and inhibitory control subscales were averaged within each reporter to create an EC composite. Cronbach's alphas for parent-reported EC were 0.80 (W1) and 0.85 (W2), and the alphas for teacher-reported EC were 0.91 (W1) and 0.92 (W2).

**Math Achievement (W1 & W2)—**The Math Calculation Skills Cluster from the Woodcock-Johnson Tests of Academic Achievement III was administered (Woodcock et al., 2001). The Math Calculation Skills Cluster is composed of the Calculation subtest – in which participants solve arithmetic problems of increasing difficulty – and Math Fluency subtest – in which participants rapidly perform simple calculations within a limited time. The Woodcock-Johnson Tests of Academic Achievement III is standardized with a mean score of 100 and standard deviation of 15. Age-standardized scores were used in the present analyses. The Woodcock-Johnson Tests of Academic Achievement III has well-documented reliability and construct validity, with individual subtests yielding reliabilities of 0.80 or higher in ethnically diverse samples (Woodcock et al., 2001).

**Demographic/Sociocultural Variables (W1)—**Information about family SES and child generation status was obtained through parent responses on an adapted version of the Family Demographic and Migration History Questionnaire, a measure previously used with other immigrant families (Roosa et al., 2008). To compute a continuous family SES index, we first calculated the mean of maternal and paternal education levels, and then averaged the standardized means of education and income.

Parent cultural orientation was measured using the English version and Chinese translation of the Culture and Social Acculturation Scale (Chen & Lee, 1996; Chen & Tse, 2010). The Culture and Social Acculturation Scale contains both an American cultural orientation (Acculturation) subscale and a Chinese cultural orientation (Enculturation) subscale. Items on the Culture and Social Acculturation Scale assess acculturation/enculturation across the domains of language fluency, media use/consumption, and social affiliations. We computed the composites of American cultural orientation and Chinese cultural orientation by averaging the standardized item scores in the respective subscales. Cronbach's alphas in the present sample were 0.87 for American cultural orientation and 0.73 for Chinese cultural orientation.

## Results

Data analyses were conducted in two steps. First, correlation analyses and *t*-tests were conducted to identify sociocultural variables that might confound the relations between self-regulation and math achievement. Second, multiple regression models were computed to test the prospective relations of self-regulation measures to math achievement, and the prospective relations of math to self-regulation. Due to the interrelations among self-regulation measures and our aim to examine their differential associations with math achievement, we tested the self-regulation measures separately using 12 multiple regressions (six regressions testing self-regulation predicting math, six regressions testing math predicting self-regulation). The confounding variables identified in the first step were included as covariates in the multiple regression models.

### Associations Between Demographic/Sociocultural Variables and Study Variables

Descriptive statistics for all study variables are presented in Table 1. Variables were screened for normality. Based on recommended skewness and kurtosis cutoffs of 2 and 7 respectively (West et al., 1995), omission errors at both waves were positively skewed and highly kurtotic, indicating that participants made relatively few omission errors. At W2, puzzle box persistence was negatively skewed and had high kurtosis, suggesting that children displayed high persistence on the task during the second wave. All other study variables were normally distributed. Robust estimation was used in testing the multiple regression models due to the nonnormally distributed variables. The sample mean for the age-standardized Math Calculation Skills Cluster scores at both waves (126.48 at W1, 125.59 at W2) was more than 1.5 standard deviations higher than the population mean. The pairwise correlations of all study variables are presented in Table 2.

To examine whether demographic/sociocultural factors were associated with the variables of interest (omission errors, commission errors, puzzle box persistence, Incongruent-Switch accuracy, Children's Behavior Questionnaire parent-report, Children's Behavior Questionnaire teacher-report, and Math Calculation Skills Cluster performance), we computed Pearson's correlations (for the continuous variables of child age, SES, parent American cultural orientation, and parent Chinese cultural orientation) and independent-sample *t*-tests (for the categorical variables of child sex and generation status).

As shown in Table 3, child age was the only demographic/sociocultural factor significantly correlated with both self-regulatory measures and math achievement. However, the remaining continuous sociocultural factors were at least marginally correlated with one or more study variables. Independent-sample *t*-tests showed significant sex differences in W1 inhibitory control, W1/W2 behavioral persistence, W2 comprehensive EF, and W1/W2 teacher-reported EC, *t*s (*df*s = 206 to 244) = −2.18 to 6.62, *p*s < .05, *d*s = 0.13 to 6.44; girls had better performance on these self-regulation measures than boys. There were also significant generational differences in W1/W2 inhibitory control and W1 parent-reported EC, *t*s (*df*s = 237 to 251) = −2.54 to −2.34, *p*s < .05, *d*s = 0.68 to 6.41; foreign-born children made fewer inhibitory control errors but were rated lower on EC by their parents. To evaluate whether the time interval between W1 and W2 was associated with self-regulation or math, we also tested the correlations of the W1/W2 time interval and all the self-regulation and math variables. None of the correlations was significant (*r* ranged from −0.10 to 0.11, *p*s > .05). Based on these results, we controlled for child age, sex, generation status, family SES, and parent Chinese and American culture orientations in the subsequent regression models.

## Testing the Bidirectional Relations Between Self-Regulation and Math Achievement

**Testing the Prospective Relations of Self-Regulation to Math—**Six multiple regressions were computed to predict W2 math achievement simultaneously from the following set of predictors (Table 4): (a) the covariates (child age, sex, generation status, family SES, parent American and Chinese culture orientations); (b) W1 math achievement; and (c) a W1 self-regulation measure. The self-regulation measures were tested in separate models. Due to the presence of nonnormally distributed self-regulation variables, the regression models were tested in Mplus 8.3 using the maximum likelihood estimation with robust standard errors (Muthén & Muthén, 1998-2017). To evaluate the power of our analyses to detect the hypothesized effects, power analyses were conducted in G*Power (Faul et al., 2009). Results suggested a sample size of 55 would be needed to reliably detect medium-sized regression coefficients in our specified models, but a sample size of 395 would be needed to reliably detect small effects. Thus, our study was adequately powered for detecting medium-sized regression coefficients, but under-powered for detecting small-sized regression coefficients.

In all six models, W1 math was a positive predictor of W2 math, suggesting cross-time consistency in math achievement. Among the covariates, child age was negatively associated with W2 math in all models, indicating that older children had lower standardized math achievement scores at W2 than younger children. Moreover, parents' American orientation was significantly and negatively associated with W2 math achievement in four models such that children whose parents were more acculturated had lower math scores at W2.

Controlling for W1 math and the covariates, two hypothesized predictions from self-regulation to math were significant: W1 behavioral persistence and parent-reported EC positively predicted W2 math. Next, we adjusted the *p*-values of the six hypothesized associations (self-regulation → math) using the Benjamini-Hochberg False Discovery Rate (FDR) correction to correct for multiple comparisons (Benjamini & Hochberg, 1995). After the adjustment, behavioral persistence and parent-reported EC became non-significant predictors of W2 math (FDR corrected *p*s = .113).

**Testing the Prospective Relations of Math to Self-Regulation—**Six regression models were tested to predict each W2 self-regulation measure from the following set of predictors (Table 5): (a) the corresponding W1 self-regulation measure, (b) covariates, and (c) W1 math. In all six models, the W1 self-regulation measure positively predicted its W2 counterpart, indicating cross-time consistency in measures of self-regulation. Regarding the covariates, child sex was a significant predictor of behavioral persistence, parent- and teacher-reported EC: boys had lower behavioral persistence and parent- and teacher-reported EC than girls. Family SES positively predicted teacher-reported EC: children from higher-SES families had higher teacher-reported EC than those from lower-SES families. In contrast, parents' American orientation negatively predicted teacher-rated EC: children with more acculturated parents had lower teacher-rated EC.

Controlling for covariates and W1 self-regulation, only one hypothesized prediction from math to self-regulation was significant: W1 math positively predicted W2 comprehensive EF, and the relation remained significant after the FDR correction (FDR corrected $p < .001$).

## Discussion

Using two waves of longitudinal data and multi-method measures, the present study tested the bidirectional associations between self-regulatory skills and math achievement among school-aged Chinese American children from immigrant families. To our knowledge, this is among the first multi-modal examinations of math – self-regulation relations in this cultural group, building upon previous analyses of cross-sectional data from the present sample (Chen et al., 2015). We predicted that both task-based and questionnaire measures of self-regulation would positively predict math achievement. We further predicted that math would positively predict self-regulation.

Regarding the relations between W1 self-regulation and W2 math achievement, we found one task-based measure (behavioral persistence) and one questionnaire measure (parent-reported EC) prospectively and positively predicted math calculation, controlling for prior levels of math. However, both associations became nonsignificant after applying the

FDR correction, necessitating caution when interpreting these findings. Concerning the relations between W1 math achievement and W2 self-regulation, we found math calculation prospectively and positively predicted the comprehensive EF measure.

Prospective relations from behavioral persistence and parent-reported EC to math calculation skills are consistent with extant research using similar self-regulatory measures with children in North America/Europe (e.g., Blair et al., 2015; Martin et al., 2013; McClelland et al., 2007; von Suchodoletz & Gunzenhauser, 2013). The significance of the findings across measurement modalities is theoretically congruent with the multiple pathways through which self-regulatory skills are posited to play a role in math proficiency development: 1) self-regulatory skills are used when performing mathematical operations, 2) self-regulatory skills enable better internalization of math instruction by facilitating completion of general academic tasks, and 3) self-regulatory skills allow for better internalization of math instruction by facilitating stronger relationships with peers and teachers who can provide academic help and generate academic motivation. However, considering these prospective associations were no longer significant following the FDR correction, these results need to be replicated with a larger sample.

The positive relation from W1 math to W2 comprehensive EF, which remained significant following the FDR correction, aligns with the work of Cameron et al. (2019), Hernández et al. (2018), and ten Braak et al. (2019), which similarly used a comprehensive task-based measure tapping several self-regulatory skills (Head-Toes-Knees-Shoulders Task) with North American/European children. This finding is also consistent with studies using latent or composite EF variables based on multiple tasks tapping working memory, inhibitory control, and cognitive flexibility (Fuhs et al., 2014; McKinnon & Blair, 2019; Nesbitt et al., 2019; Schmitt et al., 2017; Welsh et al., 2010). Together, the findings support the theory that performing mathematical operations, which requires self-regulatory resources, strengthens one’s self-regulatory skills over time (Clements et al., 2016; Peng & Kievit, 2020). Given the absence of significant reversed relations from math to questionnaire-based measures of self-regulation, the present study found less empirical support for the idea that gaining proficiency in mathematics may strengthen children’s self-regulatory skills in ways that confer broader academic or socioemotional benefits.

The null findings must also be acknowledged. In fact, only a few hypothesized associations were significant even before applying the FDR correction. Statistical power is an important concern. Meta-analytic findings suggest zero-order correlations of the prospective effects of self-regulation on subsequent math achievement in this age group tend to be of medium size (Robson et al., 2020). When using multivariate approaches to test the relations between self-regulation and math, after controlling for relevant covariates, small-to-medium effect sizes have generally been reported for prospective effects in both directions (e.g., Blair & Razza, 2007; Fuhs et al., 2014; Hernández et al., 2018; McKinnon & Blair, 2019; ten Braak et al., 2019). Though adequately powered to detect medium effects, our study lacked sufficient power to reliably detect small effects.

Alternatively, the null findings may truly reflect weaker math – self-regulation associations among our sample of Chinese American children in immigrant families. Contrary to the relatively consistent significant findings detailed in the broader literature, studies of children in China appear to have yielded a greater number of null results. We hypothesized the relations would be similar to those found among other American samples because our child participants attended American schools (negating the moderating role of school-related factors) and largely completed the assessment measures in English (negating the moderating role of language-related factors such as the language-dependent working memory load associated with performing mathematical operations). However, the plethora of null findings may suggest our participants more closely resembled native Chinese samples, raising the possibility that culture-related parenting differences could be at play. Future research can provide further clarification through direct comparison of associations among multiple American demographic groups. The weaker math – self-regulation associations in Chinese cultural samples could be due to culturally-specific parenting practices (such as increased parental involvement in math learning, high parental academic expectations, and participation in parent-initiated afterschool academic activities) facilitating higher mathematical automaticity through greater math exposure.

This interpretation is consistent with the observation that our socioeconomically diverse sample had high age-standardized math achievement scores, which were on average more than 1.5 standard deviations higher than the population mean. The negative relations we found between parent American cultural orientation and math achievement in four of our regression models align with this interpretation. The Culture and Social Acculturation Scale is a global measure of cultural orientation and does not capture math-specific cultural practices or culturally specific academic expectations. Therefore, our cultural orientation measure was not well-suited to detect culturally specific parenting factors that might be more directly related to math achievement.

Previous theoretical accounts of how increased math exposure among Chinese children moderates math – self-regulation associations have tended to focus on inhibitory control (Georgiou et al., 2020; Wei et al., 2018). However, the direct retrieval of calculation answers from long-term memory among children with more automatized math skills could decrease their need to employ self-regulatory skills more broadly when solving math problems (Evans & Stanovich, 2013). The null findings across multiple self-regulatory skills and measures reported in previous research on Chinese children (e.g., Fung et al., 2020; Lan et al., 2011) in addition to those in the present study support this idea.

Although not the study's central focus, we found significant relations between sociocultural factors and study variables that are worth discussing. First, the negative relation between children's age and age-standardized math scores observed across all models mirrors the negative association we previously found in the same sample between age and age-standardized English reading performance (Mauer et al., 2021). As we noted in that study, this pattern mimics the findings from a national sample that children from East Asian immigrant families showed decreasing relative academic proficiency over time compared to their peers (Han, 2008). This could be due to comparative improvement over time in academic proficiency among children from other demographic groups. Second, the negative relation between American cultural orientation and teacher-reported EC is expected given previous cross-cultural findings of higher performance among children in China on measures of self-regulation in comparison to North American children (Lan et al., 2011; Sabbagh et al., 2006). This suggests cultural factors, such as culturally specific values and parenting behaviors (Chen et al., 2015; Lan et al., 2011), may influence self-regulatory development in addition to academic development. Lastly, we replicated the commonly observed findings of higher SES (e.g., Sánchez-Pérez et al., 2018) and female sex being associated with higher self-regulation among school-aged children (e.g., Mous et al., 2017).

### Study Limitations and Future Directions

The present study had several limitations. First, our math measure assessed calculation skills specifically, and thus, we did not examine other domains of math achievement. As previously discussed, our cultural orientation measure was ill-suited to detect culturally specific parenting factors that are potentially important for the development of self-regulation and math proficiency. Future research should employ measures that are better able to capture such factors. Our methodological limitations also extend to our measures of attention focusing and behavioral persistence. Though we observed some significant correlations between attention focusing/behavioral persistence and math as well as other self-regulation measures, the high skewness and kurtosis of these two measures indicate that these tasks may have been too easy for many of our study participants. Replication of our results using alternative measures would provide us with greater confidence in our findings. The minimal participation of fathers in the present study is an additional limitation. Researchers have repeatedly noted the insufficient attention paid to fathers in investigations of child development (e.g., Cowan & Cowan, 2019). This common omission can and should be remedied in future related studies by encouraging both mothers and fathers to participate.

Given our lack of findings of significant prospective relations from self-regulation to math after applying an FDR correction, self-regulatory skills may be a less important determinant of math achievement among Chinese American children from immigrant families in comparison to other American subgroups due to culture-related parenting factors. Likewise, because we observed only a single prospective association from math to self-regulation (comprehensive EF), math achievement may confer more limited self-regulatory benefits to this group, which may lessen its significance for broader academic and socioemotional functioning. This has implications for instructional practice and the promotion of academic achievement in children from immigrant families. If causal relations do indeed exist between self-regulatory skills and math achievement, interventions targeting one construct as a means of bolstering the other may be less successful among children from this demographic group. Future studies can replicate our findings with more robust measures, test whether the observed associations are causal, and extend our work to investigations of other immigrant and cultural groups.

## References

Agostino A, Johnson J, & Pascual-Leone J (2010). Executive functions underlying multiplicative reasoning: Problem type matters. Journal of Experimental Child Psychology, 105(4), 286–305. 10.1016/j.jecp.2009.09.006 [PubMed: 19913238]

Anobile G, Stievano P, & Burr DC (2013). Visual sustained attention and numerosity sensitivity correlate with math achievement in children. Journal of Experimental Child Psychology, 116(2), 380–391. 10.1016/j.jecp.2013.06.006 [PubMed: 23933254]

Baddeley AD (1986). Working memory. Oxford University Press.

Barkley RA (1991). The ecological validity of laboratory and analogue assessment methods of ADHD symptoms. Journal of Abnormal Child Psychology, 19(2), 149–178. 10.1007/BF00909976 [PubMed: 2056161]

Baym CL, Corbett BA, Wright SB, & Bunge SA (2008). Neural correlates of tic severity and cognitive control in children with Tourette syndrome. Brain, 131(1), 165–179. 10.1093/brain/awm278 [PubMed: 18056159]

Benjamini Y, & Hochberg Y (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. Journal of the Royal Statistical Society: Series B (Methodological), 57(1), 289–300. 10.1111/j.2517-6161.1995.tb02031.x

Best JR, Miller PH, & Jones LL (2009). Executive functions after age 5: Changes and correlates. Developmental Review, 29(3), 180–200. 10.1016/j.dr.2009.05.002 [PubMed: 20161467]

Blair C, & Razza RP (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. Child Development, 78(2), 647–663. 10.1111/j.1467-8624.2007.01019.x [PubMed: 17381795]

Blair C, Ursache A, Greenberg M, & Vernon-Feagans L (2015). Multiple aspects of self-regulation uniquely predict mathematics but not letter–word knowledge in the early elementary grades. Developmental Psychology, 51(4), 459–472. 10.1037/a0038813 [PubMed: 25688999]

Cai J (1995). A cognitive analysis of U. S. and Chinese students' mathematical performance on tasks involving computation, simple problem solving, and complex problem solving [Monograph]. Journal for Research in Mathematics Education, 7, i–151. 10.2307/749940

Cameron CE, Kim H, Duncan RJ, Becker DR, & McClelland MM (2019). Bidirectional and co-developing associations of cognitive, mathematics, and literacy skills during kindergarten. Journal of Applied Developmental Psychology, 62, 135–144. 10.1016/j.appdev.2019.02.004

Cameron Ponitz CE, McClelland MM, Jewkes AM, Connor CM, Farris CL, & Morrison FJ (2008). Touch your toes! Developing a direct measure of behavioral regulation in early childhood. Early Childhood Research Quarterly, 23(2), 141–158. 10.1016/j.ecresq.2007.01.004

Chen SH, Main A, Zhou Q, Bunge SA, Lau N, & Chu K (2015). Effortful control and early academic achievement of Chinese American children in immigrant families. Early Childhood Research Quarterly, 30, 45–56. 10.1016/j.ecresq.2014.08.004

Chen SH, Zhou Q, Uchikoshi Y, & Bunge SA (2014). Variations on the bilingual advantage? Links of Chinese and English proficiency to Chinese American children's self-regulation. Frontiers in Psychology, 5. 10.3389/fpsyg.2014.01069

Chen X, & Lee B (1996). The cultural and social acculturation scale (child and adult version). Department of Psychology, University of Western Ontario.

Chen X, & Tse HC-H (2010). Social and psychological adjustment of Chinese Canadian children. International Journal of Behavioral Development, 34(4), 330–338. 10.1177/0165025409337546

Church JA, Bunge SA, Petersen SE, & Schlaggar BL (2017). Preparatory engagement of cognitive control networks increases late in childhood. Cerebral Cortex, 27(3), 2139–2153. 10.1093/cercor/bhw046 [PubMed: 26972753]

Clements DH, Sarama J, & Germeroth C (2016). Learning executive function and early mathematics: Directions of causal relations. Early Childhood Research Quarterly, 36, 79–90. 10.1016/j.ecresq.2015.12.009

Commodari E, & Di Blasi M (2014). The role of the different components of attention on calculation skill. Learning and Individual Differences, 32, 225–232. 10.1016/j.lindif.2014.03.005

Cowan PA, & Cowan CP (2019). Introduction: Bringing dads back into the family. Attachment & Human Development, 21(5), 419–425. 10.1080/14616734.2019.1582594 [PubMed: 30794109]

Cui J, Georgiou GK, Zhang Y, Li Y, Shu H, & Zhou X (2017). Examining the relationship between rapid automatized naming and arithmetic fluency in Chinese kindergarten children. Journal of Experimental Child Psychology, 154, 146–163. 10.1016/j.jecp.2016.10.008 [PubMed: 27883911]

Davidson MC, Amso D, Anderson LC, & Diamond A (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. Neuropsychologia, 44(11), 2037–2078. 10.1016/j.neuropsychologia.2006.02.006 [PubMed: 16580701]

DeFlorio L, Klein A, Starkey P, Swank PR, Taylor HB, Halliday SE, Beliakoff A, & Mulcahy C (2019). A study of the developing relations between self-regulation and mathematical knowledge in the context of an early math intervention. Early Childhood Research Quarterly, 46, 33–48. 10.1016/j.ecresq.2018.06.008

Diamond A (2013). Executive functions. Annual Review of Psychology, 64(1), 135–168. 10.1146/annurev-psych-113011-143750

Dulaney A, Vasilyeva M, & O'Dwyer L (2015). Individual differences in cognitive resources and elementary school mathematics achievement: Examining the roles of storage and attention. Learning and Individual Differences, 37, 55–63. 10.1016/j.lindif.2014.11.008

Eisenberg N, Cumberland A, Spinrad TL, Fabes RA, Shepard SA, Reiser M, Murphy BC, Losoya SH, & Guthrie IK (2001). The relations of regulation and emotionality to children's externalizing and internalizing problem behavior. Child Development, 72(4), 1112–1134. 10.1111/1467-8624.00337 [PubMed: 11480937]

Eisenberg N, Zhou Q, Spinrad TL, Valiente C, Fabes RA, & Liew J (2005). Relations among positive parenting, children's effortful control, and externalizing problems: A three-wave longitudinal study. Child Development, 76(5), 1055–1071. 10.1111/j.1467-8624.2005.00897.x [PubMed: 16150002]

Eriksen BA, & Eriksen CW (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. Perception & Psychophysics, 16(1), 143–149. 10.3758/BF03203267

Evans J. St. B. T., & Stanovich KE. (2013). Dual-process theories of higher cognition: Advancing the debate. Perspectives on Psychological Science, 8(3), 223–241. 10.1177/1745691612460685 [PubMed: 26172965]

Faul F, Erdfelder E, Buchner A, & Lang A-G (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. Behavior Research Methods, 41(4), 1149–1160. 10.3758/BRM.41.4.1149 [PubMed: 19897823]

Fuhs MW, Farran DC, & Nesbitt KT (2015). Prekindergarten children's executive functioning skills and achievement gains: The utility of direct assessments and teacher ratings. Journal of Educational Psychology, 107(1), 207–221. 10.1037/a0037366

Fuhs MW, Nesbitt KT, Farran DC, & Dong N (2014). Longitudinal associations between executive functioning and academic skills across content areas. Developmental Psychology, 50(6), 1698–1709. 10.1037/a0036633 [PubMed: 24749550]

Fung WK, Chung KKH, & Lam CB (2020). Mathematics, executive functioning, and visual–spatial skills in Chinese kindergarten children: Examining the bidirectionality. Journal of Experimental Child Psychology, 199, 104923. 10.1016/j.jecp.2020.104923 [PubMed: 32693935]

Garon N, Bryson SE, & Smith IM (2008). Executive function in preschoolers: A review using an integrative framework. Psychological Bulletin, 134(1), 31–60. 10.1037/0033-2909.134.1.31 [PubMed: 18193994]

Gathercole SE, Alloway TP, Willis C, & Adams A-M (2006). Working memory in children with reading disabilities. Journal of Experimental Child Psychology, 93(3), 265–281. 10.1016/j.jecp.2005.08.003 [PubMed: 16293261]

Geary DC, Bow-Thomas CC, Fan L, & Siegler RS (1993). Even before formal instruction, Chinese children outperform American children in mental addition. Cognitive Development, 8(4), 517–529. 10.1016/S0885-2014(05)80007-3

Geary DC, Bow-Thomas CC, Liu F, & Siegler RS (1996). Development of arithmetical competencies in Chinese and American children: Influence of age, language, and schooling. Child Development, 67(5), 2022–2044. 10.1111/j.1467-8624.1996.tb01841.x [PubMed: 9022227]

Georgiou GK, Wei W, Inoue T, Das JP, & Deng C (2020). Cultural influences on the relation between executive functions and academic achievement. Reading and Writing, 33(4), 991–1013. 10.1007/s11145-019-09961-8

Gerst EH, Cirino PT, Fletcher JM, & Yoshida H (2017). Cognitive and behavioral rating measures of executive function as predictors of academic outcomes in children. Child Neuropsychology, 23(4), 381–407. 10.1080/09297049.2015.1120860 [PubMed: 26678705]

Gibbs BG, Shah PG, Downey DB, & Jarvis JA (2017). The Asian American advantage in math among young children: The complex role of parenting. Sociological Perspectives, 60(2), 315–337. 10.1177/0731121416641676

Halperin JM, Wolf LE, Pascualvaca DM, Newcorn JH, Healey JM, O'Brien JD, Morganstein A, & Young JG (1988). Differential assessment of attention and impulsivity in children. Journal of the American Academy of Child & Adolescent Psychiatry, 27(3), 326–329. 10.1097/00004583-198805000-00010 [PubMed: 3379014]

Han W-J (2008). The academic trajectories of children of immigrants and their school environments. Developmental Psychology, 44(6), 1572–1590. 10.1037/a0013886 [PubMed: 18999323]

Henry KL, Knight KE, & Thornberry TP (2012). School disengagement as a predictor of dropout, delinquency, and problem substance use during adolescence and early adulthood. Journal of Youth and Adolescence, 41(2), 156–166. 10.1007/s10964-011-9665-3 [PubMed: 21523389]

Hernández MM, Eisenberg N, Valiente C, Spinrad TL, Johns SK, Berger RH, Silva KM, Diaz A, Gal-Szabo DE, Thompson MS, & Southworth J (2018). Self-regulation and academic measures across the early elementary school grades: Examining longitudinal and bidirectional associations. Early Education and Development, 29(7), 914–938. 10.1080/10409289.2018.1496722 [PubMed: 31997874]

Hughes JN, Luo W, Kwok O-M, & Loyd LK (2008). Teacher–student support, effortful engagement, and achievement: A 3-year longitudinal study. Journal of Educational Psychology, 100(1), 1–14. 10.1037/0022-0663.100.1.1 [PubMed: 19578558]

Huntsinger CS, & Jose PE (2009). Parental involvement in children's schooling: Different meanings in different cultures. Early Childhood Research Quarterly, 24(4), 398–410. 10.1016/j.ecresq.2009.07.006

Huntsinger CS, Jose PE, Larson S, Krieg D, & Shaligram C (2000). Mathematics, vocabulary, and reading development in Chinese American and European American children over the primary school years. Journal of Educational Psychology, 92, 745–760. 10.1037/0022-0663.92.4.745

Jacob R, & Parkinson J (2015). The potential for school-based interventions that target executive function to improve academic achievement: A review. Review of Educational Research, 85(4), 512–552. 10.3102/0034654314561338

Karoly P (1993). Mechanisms of self-regulation: A systems view. Annual Review of Psychology, 44(1), 23–52. 10.1146/annurev.ps.44.020193.000323

Kim H, Duran CAK, Cameron CE, & Grissmer D (2018). Developmental relations among motor and cognitive processes and mathematics skills. Child Development, 89(2), 476–494. 10.1111/cdev.12752 [PubMed: 28181219]

Knight GP, Roosa MW, Calderón-Tena CO, & Gonzales NA (2009). Methodological issues in research on Latino populations. In Villaruel FA, Carlo G, Grau JM, Azmitia M, Cabrera NJ, & Chahin TJ (Eds.), Handbook of U.S. Latino psychology: Developmental and community-based perspectives (pp. 45–62). Sage Publications, Inc.

Lan X, Legare CH, Ponitz CC, Li S, & Morrison FJ (2011). Investigating the links between the subcomponents of executive function and academic achievement: A cross-cultural analysis of Chinese and American preschoolers. Journal of Experimental Child Psychology, 108(3), 677–692. 10.1016/j.jecp.2010.11.001 [PubMed: 21238977]

Mägi K, Männamaa M, & Kikas E (2016). Profiles of self-regulation in elementary grades: Relations to math and reading skills. Learning and Individual Differences, 51, 37–48. 10.1016/j.lindif.2016.08.028

Martin A, Ryan RM, & Brooks-Gunn J (2013). Longitudinal associations among interest, persistence, supportive parenting, and achievement in early childhood. Early Childhood Research Quarterly, 28(4), 658–667. 10.1016/j.ecresq.2013.05.003

Masten AS, Roisman GI, Long JD, Burt KB, Obradović J, Riley JR, Boelcke-Stennes K, & Tellegen A (2005). Developmental cascades: Linking academic achievement and externalizing and internalizing symptoms over 20 years. Developmental Psychology, 41(5), 733–746. 10.1037/0012-1649.41.5.733 [PubMed: 16173871]

Mauer E, Zhou Q, & Uchikoshi Y (2021). A longitudinal study on bidirectional relations between executive functions and English word-level reading in Chinese American children in immigrant families. Learning and Individual Differences, 86, 101976. 10.1016/j.lindif.2021.101976 [PubMed: 33679112]

McClelland MM, Cameron CE, Connor CM, Farris CL, Jewkes AM, & Morrison FJ (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. Developmental Psychology, 43(4), 947–959. 10.1037/0012-1649.43.4.947 [PubMed: 17605527]

McClelland MM, Cameron CE, Duncan R, Bowles RP, Acock AC, Miao A, & Pratt ME (2014). Predictors of early growth in academic achievement: The head-toes-knees-shoulders task. Frontiers in Psychology, 5. 10.3389/fpsyg.2014.00599

McKinnon RD, & Blair C (2019). Bidirectional relations among executive function, teacher–child relationships, and early reading and math achievement: A cross-lagged panel analysis. Early Childhood Research Quarterly, 46, 152–165. 10.1016/j.ecresq.2018.03.011

Miller KF, Kelly M, & Zhou X (2005). Learning mathematics in China and the United States: Cross-cultural insights into the nature and course of preschool mathematical development. In Campbell JID (Ed.), Handbook of mathematical cognition (pp. 163–177). Psychology Press.

Mirowsky J, & Ross CE (2003). Education, social status, and health. Transaction Publishers.

Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, & Wager TD (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. Cognitive Psychology, 41(1), 49–100. 10.1006/cogp.1999.0734 [PubMed: 10945922]

Monette S, Bigras M, & Guay M-C (2011). The role of the executive functions in school achievement at the end of grade 1. Journal of Experimental Child Psychology, 109(2), 158–173. 10.1016/j.jecp.2011.01.008 [PubMed: 21349537]

Morrison FJ, & Grammer JK (2016). Conceptual clutter and measurement mayhem: Proposals for cross-disciplinary integration in conceptualizing and measuring executive function. In Griffin JA, McCardle P, & Freund LS (Eds.), Executive function in preschool-age children: Integrating measurement, neurodevelopment, and translational research (pp. 327–348). American Psychological Association. 10.1037/14797-015

Mous SE, Schoemaker NK, Blanken LME, Thijssen S, Ende J. van der, Polderman TJC, Jaddoe VWV, Hofman A, Verhulst FC, Tiemeier H, & White T (2017). The association of gender, age, and intelligence with neuropsychological functioning in young typically developing children: The Generation R study. Applied Neuropsychology: Child, 6(1), 22–40. 10.1080/21622965.2015.1067214 [PubMed: 26986060]

Muthén LK, & Muthén BO (1998–2017). Mplus user's guide (8th ed.). Muthén & Muthén. https://www.statmodel.com/download/usersguide/MplusUserGuideVer_8.pdf

Nesbitt KT, Fuhs MW, & Farran DC (2019). Stability and instability in the co-development of mathematics, executive function skills, and visual-motor integration from prekindergarten to first grade. Early Childhood Research Quarterly, 46, 262–274. 10.1016/j.ecresq.2018.02.003

Neuenschwander R, Röthlisberger M, Cimeli P, & Roebers CM (2012). How do different aspects of self-regulation predict successful adaptation to school? Journal of Experimental Child Psychology, 113(3), 353–371. 10.1016/j.jecp.2012.07.004 [PubMed: 22920433]

Pagani L, Fitzpatrick C, & Parent S (2012). Relating kindergarten attention to subsequent developmental pathways of classroom engagement in elementary school. Journal of Abnormal Child Psychology, 40(5), 715–725. 10.1007/s10802-011-9605-4 [PubMed: 22231874]

Pan Y, Gauvain M, Liu Z, & Cheng L (2006). American and Chinese parental involvement in young children's mathematics learning. Cognitive Development, 21(1), 17–35. 10.1016/j.cogdev.2005.08.001

Peng P, Barnes M, Wang C, Wang W, Li S, Swanson HL, Dardick W, & Tao S (2018). A meta-analysis on the relation between reading and working memory. Psychological Bulletin, 144(1), 48–76. 10.1037/bul0000124 [PubMed: 29083201]

Peng P, & Kievit RA (2020). The development of academic achievement and cognitive abilities: A bidirectional perspective. Child Development Perspectives, 14(1), 15–20. 10.1111/cdep.12352 [PubMed: 35909387]

Rea-Sandin G, Korous KM, & Causadias JM (2021). A systematic review and meta-analysis of racial/ethnic differences and similarities in executive function performance in the United States. Neuropsychology, 35(2), 141–156. 10.1037/neu0000715 [PubMed: 33764108]

Robson DA, Allen MS, & Howard SJ (2020). Self-regulation in childhood as a predictor of future outcomes: A meta-analytic review. Psychological Bulletin, 146(4), 324–354. 10.1037/bul0000227 [PubMed: 31904248]

Rodic M, Zhou X, Tikhomirova T, Wei W, Malykh S, Ismatulina V, Sabirova E, Davidova Y, Tosto MG, Lemelin J-P, & Kovas Y (2015). Cross-cultural investigation into cognitive underpinnings of individual differences in early arithmetic. Developmental Science, 18(1), 165–174. 10.1111/desc.12204 [PubMed: 24976482]

Roosa MW, Liu FF, Torres M, Gonzales NA, Knight GP, & Saenz D (2008). Sampling and recruitment in studies of cultural influences on adjustment: A case study with Mexican Americans. Journal of Family Psychology, 22(2), 293–302. 10.1037/0893-3200.22.2.293 [PubMed: 18410216]

Rothbart MK, Ahadi SA, Hershey KL, & Fisher P (2001). Investigations of temperament at three to seven years: The children's behavior questionnaire. Child Development, 72(5), 1394–1408. 10.1111/1467-8624.00355 [PubMed: 11699677]

Rothbart MK, & Bates JE (2006). Temperament. In Eisenberg N, Damon W, & Lerner RM (Eds.), Handbook of child psychology: Social, emotional, and personality development: Vol. 3 (pp. 99–166). John Wiley & Sons, Inc.

Sabbagh MA, Xu F, Carlson SM, Moses LJ, & Lee K (2006). The development of executive functioning and theory of mind. A comparison of Chinese and U.S. preschoolers. Psychological Science, 17(1), 74–81. 10.1111/j.1467-9280.2005.01667.x [PubMed: 16371147]

Sánchez-Pérez N, Fuentes LJ, Eisenberg N, & González-Salinas C (2018). Effortful control is associated with children's school functioning via learning-related behaviors. Learning and Individual Differences, 63, 78–88. 10.1016/j.lindif.2018.02.009

Schmitt SA, Geldhof GJ, Purpura DJ, Duncan R, & McClelland MM (2017). Examining the relations between executive function, math, and literacy during the transition to kindergarten: A multi-analytic approach. Journal of Educational Psychology, 109(8), 1120–1140. 10.1037/edu0000193

Sijtsma K (2009). On the use, the misuse, and the very limited usefulness of Cronbach's alpha. Psychometrika, 74(1), 107–120. 10.1007/s11336-008-9101-0 [PubMed: 20037639]

Son S-HC, Choi JY, & Kwon K-A (2019). Reciprocal associations between inhibitory control and early academic skills: Evidence from a nationally representative sample of Head Start children. Early Education and Development, 30(4), 456–477. 10.1080/10409289.2019.1572382

Soto EF, Kofler MJ, Singh LJ, Wells EL, Irwin LN, Groves NB, & Miller CE (2020). Executive functioning rating scales: Ecologically valid or construct invalid? Neuropsychology, 34(6), 605–619. 10.1037/neu0000681 [PubMed: 32730048]

Sulik MJ, Daneri MP, Pintar-Breen AI, & Blair C (2016). Self-regulation in early childhood: Theory and measurement. In Balter L & Tamis-LeMonda CS (Eds.), Child psychology: A handbook of contemporary issues (3rd ed., pp. 123–140). Taylor and Francis Inc. 10.4324/9781315764931

Swanson J, Valiente C, Lemery-Chalfant K, Bradley RH, & Eggum-Wilkens ND (2014). Longitudinal relations among parents' reactions to children's negative emotions, effortful control, and math achievement in early elementary school. Child Development, 85(5), 1932–1947. 10.1111/cdev.12260 [PubMed: 24916765]

ten Braak D, Størksen I, Idsoe T, & McClelland MM (2019). Bidirectionality in self-regulation and academic skills in play-based early childhood education. Journal of Applied Developmental Psychology, 65, 101064. 10.1016/j.appdev.2019.101064

Tharp JA, Wendelken C, Mathews CA, Marco EJ, Schreier H, & Bunge SA (2015). Tourette syndrome: Complementary insights from measures of cognitive control, eyeblink rate, and pupil ciameter. Frontiers in Psychiatry, 6. 10.3389/fpsyt.2015.00095

Toplak ME, West RF, & Stanovich KE (2013). Practitioner review: Do performance-based measures and ratings of executive function assess the same construct? Journal of Child Psychology and Psychiatry, 54(2), 131–143. 10.1111/jcpp.12001 [PubMed: 23057693]

Verdine BN, Irwin CM, Golinkoff RM, & Hirsh-Pasek K (2014). Contributions of executive function and spatial skills to preschool mathematics achievement. Journal of Experimental Child Psychology, 126, 37–51. 10.1016/j.jecp.2014.02.012 [PubMed: 24874186]

von Suchodoletz A, & Gunzenhauser C (2013). Behavior regulation and early math and vocabulary knowledge in German preschool children. Early Education and Development, 24(3), 310–331. 10.1080/10409289.2012.693428

Wei W, Guo L, Georgiou GK, Tavouktsoglou A, & Deng C (2018). Different subcomponents of executive functioning predict different growth parameters in mathematics: Evidence from a 4-year longitudinal study with Chinese children. Frontiers in Psychology, 9. 10.3389/fpsyg.2018.01037

Welsh JA, Nix RL, Blair C, Bierman KL, & Nelson KE (2010). The development of cognitive skills and gains in academic school readiness for children from low-income families. Journal of Educational Psychology, 102(1), 43–53. 10.1037/a0016738 [PubMed: 20411025]

Wendelken C, Munakata Y, Baym C, Souza M, & Bunge SA (2012). Flexible rule use: Common neural substrates in children and adults. Developmental Cognitive Neuroscience, 2(3), 329–339. 10.1016/j.dcn.2012.02.001 [PubMed: 22669034]

Wentzel KR, & Ramani GB (Eds.). (2016). Handbook of social influences in school contexts: Social-emotional, motivation, and cognitive outcomes. Routledge.

West SG, Finch JF, & Curran PJ (1995). Structural equation models with nonnormal variables: Problems and remedies. In Hoyle RH (Ed.), Structural equation modeling: Concepts, issues, and applications (pp. 56–75). Sage Publications, Inc.

Woodcock RW, McGrew KS, & Mather N (2001). Woodcock-Johnson III tests of achievement. Riverside.

Zhou X, Booth JR, Lu J, Zhao H, Butterworth B, Chen C, & Dong Q (2011). Age-independent and age-dependent neural substrate for single-digit multiplication and addition arithmetic problems. Developmental Neuropsychology, 36(3), 338–352. 10.1080/87565641.2010.549873 [PubMed: 21462011]

Zhou Q, Chen SH, & Main A (2012). Commonalities and differences in the research on children's effortful control and executive function: A call for an integrated model of self-regulation. Child Development Perspectives, 6(2), 112–121. 10.1111/j.1750-8606.2011.00176.x

Zhou Q, Hofer C, Eisenberg N, Reiser M, Spinrad TL, & Fabes RA (2007). The developmental trajectories of attention focusing, attentional and behavioral persistence, and externalizing problems during school age years. Developmental Psychology, 43(2), 369–385. 10.1037/0012-1649.43.2.369 [PubMed: 17352545]

Zhou M, & Lee J (2014). Assessing what is cultural about Asian Americans' academic advantage. Proceedings of the National Academy of Sciences, 111(23), 8321–8322. 10.1073/pnas.1407309111

Zong J, & Batalova J (2017). Chinese immigrants in the United States. Migration Policy Institute. https://www.migrationpolicy.org/article/chinese-immigrants-united-states-2016

Zorza JP, Marino J, & Acosta Mesas A (2019). Predictive influence of executive functions, effortful control, empathy, and social behavior on the academic performance in early adolescents. The Journal of Early Adolescence, 39(2), 253–279. 10.1177/0272431617737624

Zorza JP, Marino J, de Lemus S, & Acosta Mesas A (2013). Academic performance and social competence of adolescents: Predictions based on effortful control and empathy. The Spanish Journal of Psychology, 16. 10.1017/sjp.2013.87

## Table 1.

Sample descriptive statistics for mathematics and self-regulation variables at Wave 1 and Wave 2

| Variable | Wave 1 | | | | | Wave 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *N* | Mean | *SD* | Skewness | Kurtosis | *N* | Mean | *SD* | Skewness | Kurtosis |
| Math Calculation Skills Cluster | 257 | 126.48 | 15.79 | 0.13 | 1.99 | 237 | 125.59 | 14.59 | 0.00 | 0.24 |
| Omission Errors (AF) | 246 | 5.68 | 8.75 | 3.46 | 14.27 | 239 | 1.94 | 3.09 | 2.75 | 9.45 |
| Commission Errors (IC) | 246 | 9.61 | 6.48 | 1.34 | 3.72 | 239 | 9.37 | 5.64 | 1.49 | 4.25 |
| Puzzle Box Persistence (BP) | 245 | 0.82 | 0.22 | −1.47 | 1.45 | 229 | 0.94 | 0.15 | −3.71 | 14.95 |
| Incongruent-Switch Accuracy (Comprehensive EF) | 242 | 0.74 | 0.14 | −0.30 | −0.71 | 237 | 0.82 | 0.13 | −0.61 | −0.31 |
| Children's Behavior Questionnaire, Parent-Report (EC) | 253 | 4.58 | 0.68 | −0.14 | −0.27 | 235 | 4.67 | 0.76 | 0.19 | −0.35 |
| Children's Behavior Questionnaire, Teacher-Report (EC) | 215 | 5.10 | 1.00 | −0.59 | 0.14 | 208 | 5.26 | 0.93 | −0.62 | −0.08 |

*Note*. *SD* = standard deviation, AF = attention focusing, IC = inhibitory control, BP = behavioral persistence, EF = executive function, EC = effortful control.

**Table 2.**

Correlation matrix of study variables

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. W1 Math Calculation Skills Cluster | -- | | | | | | | | | | | | |
| 2. W2 Math Calculation Skills Cluster | .49$^{***}$ | -- | | | | | | | | | | | |
| 3. W1 Omission Errors (AF) | −.21$^{**}$ | −.17$^{**}$ | -- | | | | | | | | | | |
| 4. W2 Omission Errors (AF) | −.19$^{**}$ | −.19$^{**}$ | .48$^{***}$ | -- | | | | | | | | | |
| 5. W1 Commission Errors (IC) | −.15$^{*}$ | −.15$^{*}$ | −.02 | .01 | -- | | | | | | | | |
| 6. W2 Commission Errors (IC) | −.16$^{*}$ | −.17$^{*}$ | .06 | .04 | .37$^{***}$ | -- | | | | | | | |
| 7. W1 Puzzle Box Persistence (BP) | .23$^{***}$ | .17$^{*}$ | −.14$^{*}$ | −.15$^{*}$ | −.18$^{**}$ | −.15$^{*}$ | -- | | | | | | |
| 8. W2 Puzzle Box Persistence (BP) | .24$^{***}$ | .01 | −.18$^{**}$ | −.18$^{**}$ | −.12$^{+}$ | −.13$^{+}$ | .33$^{***}$ | -- | | | | | |
| 9. W1 Incongruent-Switch Accuracy (Comprehensive EF) | .28$^{***}$ | .08 | −.21$^{**}$ | −.13$^{*}$ | −.26$^{***}$ | −.18$^{**}$ | .20$^{**}$ | .10 | -- | | | | |
| 10. W2 Incongruent-Switch Accuracy (Comprehensive EF) | .31$^{***}$ | .23$^{***}$ | −.09 | −.18$^{**}$ | −.25$^{***}$ | −.23$^{***}$ | .22$^{***}$ | .20$^{**}$ | .38$^{***}$ | -- | | | |
| 11. W1 Children’s Behavior Questionnaire, Parent-Report (EC) | .11$^{+}$ | .18$^{**}$ | −.07 | −.12$^{+}$ | −.11$^{+}$ | .02 | .12$^{+}$ | .14$^{*}$ | .13$^{+}$ | .11 | -- | | |
| 12. W2 Children’s Behavior Questionnaire, Parent-Report (EC) | .16$^{*}$ | .19$^{**}$ | −.08 | −.16$^{*}$ | −.17$^{**}$ | −.11$^{+}$ | .18$^{**}$ | .21$^{**}$ | .14$^{*}$ | .15$^{*}$ | .65$^{***}$ | -- | |
| 13. W1 Children’s Behavior Questionnaire, Teacher-Report (EC) | .32$^{***}$ | .26$^{***}$ | −.23$^{***}$ | −.19$^{**}$ | −.16$^{*}$ | −.11 | .15$^{*}$ | .21$^{**}$ | .17$^{*}$ | .39$^{***}$ | .23$^{***}$ | .28$^{***}$ | -- |
| 14. W2 Children’s Behavior Questionnaire, Teacher-Report (EC) | .23$^{***}$ | .25$^{***}$ | −.11 | −.16$^{*}$ | −.19$^{**}$ | −.13$^{+}$ | .25$^{***}$ | .23$^{**}$ | .22$^{**}$ | .23$^{***}$ | .29$^{***}$ | .35$^{***}$ | .49$^{***}$ |

*Note.* The *n*s for the correlations ranged from 175 to 252; AF = attention focusing, IC = inhibitory control, BP = behavioral persistence, EF = executive function, EC = effortful control;

$^{+}p < .10$,

$^{*}p < .05$,

$^{**}p < .01$,

$^{***}p < .001$.

**Table 3.**

Correlations between continuous demographic/sociocultural factors and study variables

| | Child Age | Family SES | Parent American Cultural Orientation | Parent Chinese Cultural Orientation |
|---|---|---|---|---|
| W1 Math Calculation Skills Cluster | 0.28*** | 0.04 | 0.03 | 0.01 |
| W2 Math Calculation Skills Cluster | −0.12+ | 0.00 | −0.09 | 0.06 |
| W1 Omission Errors (AF) | −0.15* | −0.01 | −0.02 | −0.11+ |
| W2 Omission Errors (AF) | −0.12+ | −0.02 | −0.09 | −0.06 |
| W1 Commission Errors (IC) | −0.14* | 0.14* | 0.13* | −0.04 |
| W2 Commission Errors (IC) | −0.16* | 0.15* | 0.13+ | −0.10 |
| W1 Puzzle Box Persistence (BP) | 0.29*** | −0.11+ | −0.15* | 0.09 |
| W2 Puzzle Box Persistence (BP) | 0.25*** | −0.07 | −0.07 | −0.00 |
| W1 Incongruent-Switch Accuracy (Comprehensive EF) | 0.31*** | 0.04 | −0.02 | 0.01 |
| W2 Incongruent-Switch Accuracy (Comprehensive EF) | 0.13+ | 0.10 | 0.09 | 0.07 |
| W1 Children's Behavior Questionnaire, Parent-Report (EC) | −0.04 | 0.14* | 0.16* | 0.09 |
| W2 Children's Behavior Questionnaire, Parent-Report (EC) | 0.04 | 0.16* | 0.14* | 0.04 |
| W1 Children's Behavior Questionnaire, Teacher-Report (EC) | 0.04 | −0.02 | 0.01 | 0.03 |
| W2 Children's Behavior Questionnaire, Teacher-Report (EC) | 0.06 | 0.05 | −0.05 | 0.02 |

*Note.* The *n*s for the correlations ranged from 199 to 256; SES = socioeconomic status, AF = attention focusing, IC = inhibitory control, BP = behavioral persistence, EF = executive function, EC = effortful control;

+ $p < .10$,

* $p < .05$,

** $p < .01$,

*** $p < .001$.

**Table 4.**

Multiple regressions predicting W2 math achievement from W1 self-regulation

| | Regression 1 W1 AF-> W2 Math | | Regression 2 W1 IC-> W2 Math | | Regression 3 W1 BP-> W2 Math | | Regression 4 W1 Comp EF-> W2 Math | | Regression 5 W1 PR EC-> W2 Math | | Regression 6 W1 TR EC->W2 Math | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Predictors** | ***B (SE)*** | **β** | ***B (SE)*** | **β** | ***B (SE)*** | **β** | ***B (SE)*** | **β** | ***B (SE)*** | **β** | ***B (SE)*** | **β** |
| W1 Low AF | $-0.18^{+}$ (0.10) | −0.10 | | | | | | | | | | |
| W1 Low IC | | | −0.17 (0.14) | −0.07 | | | | | | | | |
| W1 BP | | | | | $8.52^{*}$ (4.27) | 0.13 | | | | | | |
| W1 Comprehensive EF | | | | | | | 3.73 (6.59) | 0.04 | | | | |
| W1 Parent-Report EC | | | | | | | | | $2.39^{*}$ (1.09) | 0.11 | | |
| W1 Teacher-Report EC | | | | | | | | | | | $1.78^{+}$ (0.95) | 0.12 |
| W1 Math | $0.49^{***}$ (0.05) | 0.55 | $0.50^{***}$ (0.05) | 0.55 | $0.51^{***}$ (0.05) | 0.56 | $0.50^{***}$ (0.05) | 0.55 | $0.50^{***}$ (0.05) | 0.55 | $0.48^{***}$ (0.06) | 0.54 |
| Child Age | $-6.47^{***}$ (1.14) | −0.32 | $-6.33^{***}$ (1.14) | −0.31 | $-6.95^{***}$ (1.17) | −0.34 | $-6.29^{***}$ (1.19) | −0.31 | $-5.83^{***}$ (1.13) | −0.29 | $-5.84^{***}$ (1.22) | −0.28 |
| Child Sex (0 = girls, 1 = boys) | 0.59 (1.69) | 0.02 | 0.75 (1.74) | 0.03 | 1.71 (1.69) | 0.06 | 0.87 (1.71) | 0.03 | 1.36 (1.65) | 0.05 | 1.43 (1.87) | 0.05 |
| Child Generation Status (0 = 1st, 1 = 2nd) | −1.77 (2.13) | −0.05 | −1.56 (2.12) | −0.04 | −2.10 (2.08) | −0.06 | −1.63 (2.15) | −0.05 | −2.54 (2.05) | −0.07 | −3.43 (2.24) | −0.09 |
| Family SES | 0.86 (1.27) | 0.05 | 1.05 (1.24) | 0.06 | 1.29 (1.09) | 0.07 | 0.98 (1.21) | 0.06 | 1.04 (1.19) | 0.06 | 1.96 (1.38) | 0.11 |
| Parent American Cultural Orientation | $-3.63^{*}$ (1.80) | −0.15 | $-3.53^{*}$ (1.79) | −0.14 | −2.70 (1.70) | −0.11 | $-3.58^{+}$ (1.85) | −0.15 | $-3.67^{*}$ (1.81) | −0.15 | $-4.58^{*}$ (1.90) | −0.19 |
| Parent Chinese Cultural Orientation | 1.39 (1.89) | 0.05 | 1.53 (1.86) | 0.05 | 0.45 (1.86) | 0.02 | 1.53 (1.89) | 0.05 | 1.24 (1.85) | 0.04 | 2.03 (1.87) | 0.07 |
| $R^2$ | $.35^{***}$ | | $.35^{***}$ | | $.37^{***}$ | | $.33^{***}$ | | $.36^{***}$ | | $.38^{***}$ | |
| *N* | 210 | | 210 | | 209 | | 209 | | 216 | | 188 | |

*Note.* AF = attention focusing, IC = inhibitory control, BP = behavioral persistence, Comp EF = comprehensive executive function, PR EC = parent-reported effortful control, TR EC = teacher-reported effortful control, SES = socioeconomic status, B = unstandardized regression coefficient, *SE* = standard error, β = standardized regression coefficient;

$^{+}p < .10$,

$^{*}p < .05$,

$^{**}p < .01$,

$^{***}p < .001$.

**Table 5.**

Multiple regressions predicting W2 self-regulation from W1 math achievement

| | Regression 1 W1 Math-> W2 AF | | Regression 2 W1 Math-> W2 IC | | Regression 3 W1 Math-> W2 BP | | Regression 4 W1 Math-> W2 Comp EF | | Regression 5 W1 Math-> W2 PR EC | | Regression 6 W1 Math-> W2 TR EC | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Predictors** | ***B (SE)*** | **β** | ***B (SE)*** | **β** | ***B (SE)*** | **β** | ***B (SE)*** | **β** | ***B (SE)*** | **β** | ***B (SE)*** | **β** |
| W1 Math | −0.01 (0.02) | −0.07 | $-0.04^{+}$ (0.02) | −0.11 | $0.00^{+}$ (0.00) | 0.19 | $0.00^{***}$ (0.00) | 0.24 | 0.00 (0.00) | 0.07 | $0.01^{+}$ (0.00) | 0.11 |
| W1 Low AF | $0.17^{**}$ (0.05) | 0.48 | | | | | | | | | | |
| W1 Low IC | | | $0.25^{**}$ (0.09) | 0.29 | | | | | | | | |
| W1 BP | | | | | $0.15^{*}$ (0.07) | 0.24 | | | | | | |
| W1 Comprehensive EF | | | | | | | $0.30^{***}$ (0.07) | 0.32 | | | | |
| W1 Parent-Report EC | | | | | | | | | $0.71^{***}$ (0.05) | 0.64 | | |
| W1 Teacher-Report EC | | | | | | | | | | | $0.35^{***}$ (0.07) | 0.36 |
| Age | 0.09 (0.27) | 0.02 | −0.58 (0.50) | −0.07 | $0.02^{+}$ (0.01) | 0.11 | −0.01 (0.01) | −0.07 | 0.05 (0.06) | 0.05 | −0.04 (0.07) | −0.03 |
| Sex (0 = girls, 1 = boys) | −0.12 (0.36) | −0.02 | 0.06 (0.78) | 0.01 | $-0.05^{*}$ (0.02) | −0.16 | −0.03 (0.02) | −0.10 | $-0.21^{**}$ (0.08) | −0.14 | $-0.65^{***}$ (0.12) | −0.35 |
| Generation Status (0 = 1st, 1 = 2nd) | −0.05 (0.47) | −0.01 | $1.37^{+}$ (0.74) | 0.10 | 0.03 (0.03) | 0.08 | 0.01 (0.02) | 0.02 | −0.11 (0.09) | −0.06 | −0.05 (0.15) | −0.02 |
| Family SES | 0.36 (0.28) | 0.10 | 0.16 (0.51) | 0.02 | −0.01 (0.01) | −0.04 | 0.01 (0.01) | 0.05 | 0.06 (0.06) | 0.07 | $0.20^{*}$ (0.09) | 0.18 |
| Parent American Cultural Orientation | −0.56 (0.36) | −0.12 | 0.47 (0.76) | 0.05 | −0.01 (0.03) | −0.02 | 0.01 (0.02) | 0.04 | 0.05 (0.09) | 0.04 | $-0.24^{*}$ (0.12) | −0.17 |
| Parent Chinese Cultural Orientation | 0.07 (0.31) | 0.01 | $-1.23^{+}$ (0.70) | −0.11 | −0.01 (0.01) | −0.04 | 0.02 (0.02) | 0.08 | −0.02 (0.08) | −0.01 | 0.04 (0.13) | 0.02 |
| $R^2$ | $.26^{*}$ | | $.17^{**}$ | | $.18^{*}$ | | $.21^{***}$ | | $.46^{***}$ | | $.38^{***}$ | |
| *N* | 212 | | 212 | | 203 | | 210 | | 214 | | 164 | |

*Note.* AF = attention focusing, IC = inhibitory control, BP = behavioral persistence, EF = executive function, EC = effortful control, SES = socioeconomic status, B = unstandardized regression coefficient, *SE* = standard error, β = standardized regression coefficient;

$^{+}p < .10$,

$^{*}p < .05$,

$^{**}p < .01$,

$^{***}p < .001$.