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Research Paper

Early self-regulation and academic competence in the preschool-to-primary school transition: The mediating role of behavioral problems

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ABSTRACT

Early self-regulatory abilities are considered key predictors of children's behavioral problems and academic competence. However, little is known about whether behavioral problems mediate the association between self-regulation and academic competence, after accounting for key child and family characteristics, during the transition from less structured preschool to more structured primary school contexts. Hence, this study investigated whether behavioral problems at age 5—specifically peer relationship problems, hyperactivity, and conduct problems—mediate the relations between self-regulatory abilities at ages 3–4 (phonological working memory, inhibitory control, cognitive flexibility, delay of gratification, and parent-reported effortful control) and academic competence across receptive vocabulary, mathematical, and scientific domains at ages 6–7, while accounting for relevant covariates (e.g., negative affectivity, socio-economic status). The study drew on data from 1,931 children from a large-scale German longitudinal study. Structural equation modeling showed that self-regulatory facets such as phonological working memory and inhibitory control were directly related to later academic competence both overall and across domains, whereas only parent-reported EC was directly related with behavioral problems. Behavioral problems, in turn, were related to overall academic competence and to the domains of receptive vocabulary and mathematics, but not to science. Accordingly, an indirect pathway via behavioral problems emerged only for parent-reported EC in relation to academic competence — overall and in the domains of mathematics and receptive vocabulary. These results underscore the importance of supporting early self-regulatory abilities—particularly effortful control—through targeted interventions that may help reduce behavioral problems and promote academic competence during the transition to formal schooling.

The transition from preschool to primary school marks a critical period during which students face new demands within the classroom learning environment. Self-regulation refers to the "internal and transitional processes that guide individuals in goal-directed activities" (Karoly, 1993). Early self-regulation is linked to fewer behavioral problems—such as aggression, impulsivity, and defiance—and to better academic competence (Denham et al., 2012). However, the pathways linking self-regulation to academic competence—particularly the potential mediating role of behavioral problems—are relatively underexplored (Eisenberg et al., 2005, 2010). Furthermore, little is known about how these mediating relations may be influenced by temperamental (e.g., negative affectivity, surgency) and socio-demographic factors (e.g., socio-economic status), which can serve as important developmental contexts (Bronfenbrenner & Morris, 2006; Liew et al., 2019, 2020; Rimm-Kaufman & Pianta, 2000), particularly during the transition from a less structured preschool to a more structured primary school environment.

Building on various heuristic models (Eisenberg et al., 2005, 2010; Liew et al., 2019, 2020), the present study draws on data from a large-scale German longitudinal study to analyze these processes in context. Specifically, it investigates whether and how behavioral problems mediate the relations between self-regulation and academic competence, while accounting for key temperamental and socio-demographic factors. The study analyses whether various self-regulatory facets assessed at ages 3–4: inhibitory control, cognitive flexibility, phonological working memory, parent-reported effortful control (EC), and delay of gratification predict later academic competence—across receptive vocabulary and mathematical and scientific domains at ages 6–7—via the potential mediating role of behavioral problems (peer relationship problems, hyperactivity, and conduct problems) at age 5, while also controlling for relevant covariates (e.g., negative affectivity, surgency, socio-economic status).

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1. Theoretical background

The following section outlines the theoretical framework of self-regulation in the preschool years and the conceptual models that propose both direct and indirect pathways linking self-regulation to academic competence, with particular emphasis on the mediating role of behavioral problems.

1.1. Self-regulation in the preschool years

Self-regulation is a multifaceted construct encompassing cognitive and emotional processes that enable children to manage their thoughts, behaviors, and emotions in goal-directed ways (Bailey & Jones, 2019). These processes have been conceptualized within two overlapping yet distinct traditions: executive function (EF) and effortful control (EC; Bailey & Jones, 2019; Jones et al., 2016; Kälin & Roebers, 2021). EF refers to the cognitive processes that regulate attention, control, and goal-directed behavior. EC is rooted in temperament research and concerns the intentional management of thoughts, behaviors, and emotions (Jones et al., 2016). EF and EC furthermore include a range of interrelated facets—such as phonological working memory, inhibitory control, cognitive flexibility, effortful control, and delay of gratification—which, despite their proposed conceptual distinctiveness, are often theorized and empirically modeled as reflecting a single underlying self-regulatory facet in the preschool years (Kälin & Roebers, 2021; Lin et al., 2019). However, not all studies support a strictly unidimensional structure (Frechette et al., 2021). Alternative theoretical accounts propose intermediate models in which self-regulation may be organized into partially differentiated facets (Heinze et al., 2025), most commonly distinguishing between the more emotionally neutral EF and the more emotion-related self-regulatory facets (Bailey & Jones, 2019; Jones et al., 2016; Zelazo & Carlson, 2012).

In line with these distinctions, the individual facets commonly used to assess self-regulation may be differentiated according to the regulatory demands they place on children. For instance, inhibitory control and cognitive flexibility reflect processes involved in overriding dominant responses and flexibly shifting between tasks, respectively, and are typically assessed in emotionally neutral contexts (Bailey & Jones, 2019). Phonological working memory likewise supports the temporary maintenance and manipulation of information and is also engaged in cognitive or emotionally neutral contexts (Bailey & Jones, 2019; Zelazo & Carlson, 2012). In contrast, other facets more strongly reflect emotion-related regulatory processes. For instance, parent-reported EC captures children's capacity to regulate attention, behavior, and emotion in everyday situations, while delay of gratification assesses the ability to resist immediate rewards in favor of longer-term goals (Jones et al., 2016; Mischel & Gilligan, 1964). Although both facets may also encompass regulation in more neutral situations, they are often elicited in emotionally salient contexts (Bailey & Jones, 2019; Zhou et al., 2012; Zelazo & Carlson, 2012).

Yet, despite these conceptual differentiation, these distinctions may not always emerge empirically. When analyzing the factor structure of these facets, prior analyses failed to yield clear support for either a unidimensional, two-factor, or multifactor solution (Doshi et al., 2024, 2026). In light of these findings, and given that the present study utilizes the same dataset, adopting an integrated framework of self-regulation (e.g., Bailey & Jones, 2019; Jones et al., 2016) appears to be more useful, as it allows each facet to be analyzed individually while still acknowledging areas of conceptual overlap.

1.2. Self-regulation and academic competence: The mediating role of behavioral problems

The role of these self-regulatory facets in predicting academic competence both directly and indirectly via behavioral problems, has been highlighted in various overlapping heuristic models (Eisenberg et al., 2005; 2010). Particularly, the models proposed by Eisenberg et al. (2005; 2010) suggest that children having poor self-regulation are more likely to exhibit behavioral problems (e.g., aggression, impulsivity, or negativity in the classroom). These behavioral problems, in turn, may hinder children's ability to engage effectively in learning, thereby impacting their academic competence.

The model also specifies another mediating mechanism through classroom-related relationships and engagement (e.g., peer relationships and positive relationships with teachers), which may be influenced by children's self-regulatory abilities—both directly and indirectly via behavioral problems—and, in turn, impact academic competence. However, given the interconnected nature of these processes, the present study focuses specifically on behavioral problems as a mediating mechanism, allowing for a more detailed analysis of one key pathway linking self-regulation to academic competence. This focus is also important in the context of Liew et al.'s (2019, 2020) bio-social-ecological systems perspective, which integrates Bronfenbrenner and Morris's (2006) bioecological model with Eisenberg's frameworks (Eisenberg et al., 2005, 2010). Within this model, the reciprocal interactions between children and their environments—shaped by child characteristics such as temperament and contextual factors like family socioeconomic status—play a critical role in shaping the mediating pathway (Bronfenbrenner & Morris, 2006; Liew et al., 2019, 2020; Rimm-Kaufman & Pianta, 2000).

2. The preschool context and its relevance for the mediating pathway during the preschool-to-primary school transition

However, it is noteworthy that these previously suggested models have been largely developed in educational contexts characterized by relatively structured, adult-directed preschool environments (e.g., as in the United States; Wall et al., 2015). In such contexts, children's self-regulation may be closely tied to their ability to comply with externally set rules, follow instructions, and adapt to teacher-led classroom routines. Because these environments may limit opportunities for autonomous and self-directed learning, children could develop relatively lower self-regulation (Eberhart et al., 2024). As a result, behavioral problems may play a particularly prominent mediating role, as children with lower self-regulation may be more likely to exhibit behavioral problems, which in turn may interfere with their academic competence (Montroy et al., 2014; Wall et al., 2015). However, it remains unclear whether these mediation processes operate in the same way in less structured, child-centered preschool educational contexts.

This question is especially relevant in the German preschool system, which differs from more instruction-oriented contexts and therefore may provide a meaningful setting in which to examine the generalizability of these proposed mediation frameworks. In this system, children typically transition from preschool to primary school around age 6 or 7, with the first year of primary school marking a shift toward more formal or instructional academic learning (e.g., in reading, writing, and arithmetic; Blair, 2002; Rimm-Kaufman & Pianta, 2000). Preschool, which serves children aged 3 to 5 or 6, takes a notably different approach. Unlike primary schools, it balances free play with loosely structured activities that prioritize children's interests, following an "open concept" pedagogical approach (Wall et al., 2015, p. 64). Children can freely choose among different activities, such as construction, reading, or creative work. These learning opportunities are supported by teacher- and peer-led interactions (e.g., sustained shared thinking, constructivist approaches, child-centered and situation-oriented learning), fostering autonomy and interactive play (Rademacher et al., 2022; Smidt & Rossbach, 2016; Schmerse, 2020). Herein, academic competence, including early language development, is embedded in everyday interactions rather than delivered through a formal curriculum (Wall et al., 2015, p. 53). Hence, when compared with more structured preschool settings, such autonomy has been associated with the development of better self-regulatory abilities (Barter et al., 2014), which lead to fewer behavioral problems and, consequently, better academic competence (Trommsdorff, 2009; Wall et al., 2015).

Given these preschool contexts, analyzing these models during the transition from a less structured preschool to a more structured primary school environment is important for determining the robustness of the proposed mediation pathways. In particular, it helps determine whether children's exposure to autonomy-oriented environment in preschool fosters the development of better self-regulatory abilities, which in turn reduces behavioral problems among them and supports better academic competence during the primary school transition (Doshi et al., 2026; Eisenberg et al., 2010). However, before addressing this pathway, it is important to understand how early self-regulation, behavioral problems, and later academic competence are related in previous research.

2.1. Empirical evidence

Empirical evidence regarding the relations between self-regulation, behavioral problems, and academic competence has remained mixed. Although not analyzed in the present study, these inconsistencies may partly reflect the notion that different facets of self-regulation (emotionally neutral EF vs. emotion-related) may relate to outcomes in somewhat distinct ways depending on the preschool context. For example, Kim et al. (2013) found that inhibitory control and cognitive flexibility (emotionally neutral EF) significantly predicted academic competence in mathematics and reading, as assessed by parents and teachers. In contrast, children's ability to delay gratification (emotion-related, e.g., snack delay, tongue task, toy peek) was associated with behavioral problems between ages 5 and 8 (Denham et al., 2012). Notably, both studies were conducted in relatively structured, adult-directed preschool contexts (e.g., the United States). Supporting the relevance of less structured, play-based preschool contexts, Backer-Grøndahl et al. (2019); the only study to test differential relations statistically) found that delay of gratification was specifically related to behavioral problems, whereas inhibitory control and cognitive flexibility were associated with both academic competence and behavioral problems.

Moreover, behavioral problems were found to mediate the association between delay of gratification and academic competence in mathematics and reading (Backer-Grøndahl et al., 2019), indicating that the mediation pathway may be facet-specific. However, evidence for such mediating processes remains limited to this study, particularly in less structured preschool contexts. Accordingly, the present study analyses whether behavioral problems similarly mediate the associations between various self-regulatory abilities and academic competence across various domains during the transition from preschool to primary school, while also accounting for relevant covariates.

2.2. The impact of various child and family characteristics on the mediating relations

As key developmental contexts, temperament and socio-demographic factors may play a crucial role in shaping the mediating pathway linking self-regulation and academic competence (Bronfenbrenner & Morris, 2006; Liew et al., 2019, 2020). Accordingly, several factors are included as controls in this study (Rimm-Kaufman & Pianta, 2000), as each may influence self-regulation, behavioral problems, and academic competence, respectively. First, children high in negative affectivity or surgency exhibit tendencies such as anger, frustration, extraversion, or impulsivity. These temperamental characteristics have been shown to hinder the development of self-regulatory abilities (Blair & Razza, 2007; Zhou et al., 2010), increase the likelihood of behavioral problems (Eisenberg et al., 2005), and affect early academic competence (Blair & Razza, 2007; Valiente et al., 2011). Second, socioeconomic status may play a role, as children from lower-income backgrounds often have fewer opportunities to practice self-regulation, exhibit higher levels of behavioral problems (Bradley & Corwyn, 2002), and tend to show lower levels of early academic competence (Duncan et al., 2007). Third, gender differences may influence self-regulatory abilities as well as behavioral problems, potentially affecting how these pathways operate for boys and girls during the preschool-to-primary school transition (Denham et al., 2012).

In addition to these temperamental and socio-demographic influences, other child-level and contextual factors—such as prior cognitive abilities, early academic competence, and cultural or socio-demographic factors (e.g., home interaction language)—may further shape the mediating relations. Non-verbal cognitive functioning and early receptive vocabulary have been shown to predict self-regulation (Cadima et al., 2019), and their associations with behavioral problems suggest that children with more advanced receptive vocabulary not only develop better self-regulation but also exhibit fewer behavioral difficulties, which may, in turn, enhance later academic competence (Huang et al., 2024). Alongside receptive vocabulary, prior academic competence has been found to influence preschool self-regulatory abilities (Cadima et al., 2019) and primary school academic competence (Blair & Razza, 2007; Doshi et al., 2024). Furthermore, cultural factors such as home interaction language may shape these relations by influencing how parents emphasize particular temperamental and behavioral patterns (Zhou et al., 2010), which can subsequently affect children's academic competence at school entry (Zhou et al., 2010). Accordingly, it is expected that the included child and family characteristics are associated with self-regulation, behavioral problems, and academic competence and are therefore included as control variables in the present analyses.

2.3. Current study

To investigate these relations empirically, the present study used a longitudinal German sample to analyze whether behavioral problems at age 5 mediate the relations between various self-regulatory facets (ages 3–4) and academic competence during the transition from unstructured preschool to structured primary school—both overall and across receptive vocabulary, mathematical, and scientific domains (ages 6–7), while accounting for relevant control variables. Although this is not the main focus of the study, the direct relations of the self-regulatory facets with behavioral problems and academic competence were also reported.

In line with prior work using the theoretical models (Eisenberg et al., 2005, 2010; Liew et al., 2019, 2020), and the same dataset (Doshi et al., 2024, 2026) it was hypothesized that children with better early self-regulation—particularly inhibitory control and phonological working memory—would demonstrate higher academic competence across domains of receptive vocabulary, mathematics and science (Backer-Grøndahl et al., 2019; Doshi et al., 2024). Additionally, better parent-reported EC was expected to be associated with fewer behavioral problems at age 5, which, in turn, could support higher academic competence (Backer-Grøndahl et al., 2019; Doshi et al., 2026). However, given the limited prior evidence regarding other self-regulatory facets beyond phonological working memory, inhibitory control, and parent-reported EC (Backer-Grøndahl et al., 2019; Doshi et al., 2024, 2026), analyses concerning the indirect associations of the other self-regulatory facets with academic competence were considered exploratory.

3. Methods

3.1. Participants

This study drew on data from the newborn cohort (NEPS-SC1) of the ongoing German Education Panel Study (NEPS, Blossfeld & Rossbach, 2019; NEPS Network, 2022). Specifically, data from the fourth measurement point (T1) as well as from four subsequent time points (T2–T5) were included, covering the period until children were 7 years old (see Appendix A for details). The present analysis therefore included those children who participated in Wave 8 (i.e., after school entry) of the study (N = 1,931). All direct measures were assessed in the children's homes, and individual tests were administered using a tablet computer. In addition to the direct measures, parents provided information on their children's characteristics and demographic information at each time point. Parent- and child-reported measures were administered in German. Most instruments used official German versions of the tests, while others were carefully tested and validated within the NEPS framework. Comprehensive documentation of the questionnaires and survey instruments—including German and English versions—is available on the official NEPS/LIfBi website (e.g., FDZ LIfBi, 2024). Methodological and technical reports for specific competence domains further describe the development and scaling of NEPS instruments (for details, see below).

3.2. *Measures*

3.2.1. *Self-regulatory facets*

Phonological working memory (T1, age 3). The digit span task was based on Baddeley's working memory model and adapted from the German version of the Kaufman Assessment Battery for Children (K-ABC; internal consistency: .86; Melchers & Preuß, 2009). Administered via a tablet to 3-year-olds, the task presented sequences of auditory digits which children reproduced in the same order. The sequence length increased until the child failed to recall them correctly. A practice phase was implemented to ensure understanding, but was not included in scoring. The test phase included five sets of three items, with the first two items in the first set serving as learning items. During this phase, the children received feedback from the tablet, based on which they could repeat the task if necessary. The items were included in the total score only if recalled correctly on the first attempt. The maximum score was 15, based on the total number of correctly recalled learning and test items.

Inhibitory control (T2, age 4). The child-adapted version of Eriksen's flanker task (Eriksen & Eriksen, 1974) assesses inhibitory control with high test-retest reliability and an intraclass correlation of .92 (Bauer & Zelazo, 2014). Presented on a tablet in the NEPS, the task used fish as directional indicators. Congruent trials had fish facing the same direction (< < < < <), while incongruent trials had the middle fish facing the opposite direction (< < > < <). The children were instructed to focus on the middle fish and press the corresponding button while ignoring the outer fish. After being introduced to the keyboard and buttons, they completed three practice phases, each with seven items, requiring at least three correct responses per phase to proceed. The test phase included 30 items (20 congruent, 10 incongruent). For this study, inhibitory control was measured as the proportion of correct responses (0.0–1.0) in the incongruent trials (Doshi et al., 2024).

Cognitive flexibility (T2, age 4). This was measured using a second flanker task with a rule change (Eriksen & Eriksen, 1974). The children were asked to focus on the direction of the outer fish while ignoring the middle fish (< < > < <) and press the corresponding button as quickly as possible. This switching variant of the flanker task had previously been employed in other studies as an indicator of cognitive flexibility in preschoolers (e.g., Gashaj et al., 2019; Oeri & Roebers, 2022). It was administered only to children who successfully completed the first and second practice phases of the inhibitory control task. The task comprised three practice items, followed by sixteen test items: eight congruent and eight incongruent items. In this study, the proportion of correct responses (ranging from 0.0 to 1.0) in the incongruent trials was used as a measure of cognitive flexibility.

Delay of gratification (T1, age 3). The children's ability to delay gratification was measured using the setting and waiting paradigm (Mischel & Gilligan, 1964) at age 3. In this task, children were presented with two gifts, one large and one small. A USB stick placed between the gifts allowed the children to indicate if they did not want to wait for an unknown amount of time before receiving the gift. Pressing the USB stick resulted in them receiving the small gift immediately, but waiting for 3 minutes (181 seconds) led to them receiving the larger gift. The child's decision to wait (1 = *waited*, 0 = *did not wait*) was used as an indicator of delay of gratification. Similar paradigms in preschool-aged children have shown acceptable reliability and predictive validity, with performance linked to later self-regulatory and academic outcomes (Lemmon & Moore, 2007; Watts et al., 2018).

Parent-report measure on effortful control (T1 and T2, ages 3 and 4). This was assessed via parent report using the very short German version of the Child Behavioral Questionnaire (CBQ-VSF; Putnam & Rothbart, 2006) when children were age 3 and 4. Three items from the CBQ-VFS were included in the NEPS, such as "shows a high level of concentration when drawing or coloring in a book," "sometimes becomes absorbed in a picture book and looks at it for a long time," and "enjoys gentle rhythmic activities, such as rocking or swaying." The parents rated each item on a six-point Likert scale, ranging from 0 (*does not apply at all*) to 1 (*completely applies*). While the CBQ-VSF has demonstrated acceptable reliability in previous research (α = .62 –.78; Putnam & Rothbart, 2006) and has been shown to validly assess children's temperament (Kälin & Roebers, 2021), internal consistency in the current study was low at each age (α = .26 at age 3, α = .38 at age 4). However, correlations across the two measurement points were moderate (.51), and therefore, to improve reliability, the measure was averaged across the individual items and waves at ages 3 and 4 (α = .56).

3.2.2. *Behavioral problems*

Peer relationship problems, hyperactivity, and conduct problems (T3, age 5). The parents rated their children's behavioral problems on the following three subscales from the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997): peer relationship problems (e.g., rather solitary, tends to play alone; Doshi et al., 2026), hyperactivity (e.g., restless, overactive), and conduct problems (e.g., often has tantrums or a hot temper). Each subscale comprised five items, and the parents rated each item using a three-point Likert scale, ranging from 0 (*does not apply*) to 2 (*certainly applies*). Although the reliability for peer relationship problems (α = .57), hyperactivity (α = .73), and conduct problems (α = .52) at age 5 was not high, the SDQ is widely used measure to assess behavioral problems with acceptable reliability (weighted average Cronbach's alpha = .79; Kersten et al., 2016). Given this, a confirmatory factor analysis was conducted to account for measurement error and capture the shared variance across the three subscales. A second-order confirmatory factor analysis ($\chi 2$ = 440.840; df = 87, p < .001, CFI = .94, RMSEA = .05, WRMR = 1.70) modelling a common latent factor showed a better fit than the first-order model with the three separate factors ($\chi 2$ = 1,487.29; df = 90, p < .001, CFI = .76, RMSEA = .09, WRMR = 3.13). Based on this, the mean scores for peer relationship problems, hyperactivity, and conduct problems were included as manifest variables to create a latent variable, labelled "behavioral problems" (see Appendix B).

3.2.3. *Academic competence*

Mathematical competence (T4, age 6). The children's mathematical competence was assessed at age 6 (Neumann et al., 2013), based on the concept of mathematical literacy as defined by PISA. The test, administered using a tablet computer, consisted of 25 items. The NEPS framework, it evaluates several content-related components: age-appropriate knowledge of sets, numbers, and operations as well as understanding numbers and their relations, alongside performing contextual calculations. These components are specified as follows: Units and measurements involve using numbers to quantify, organize, and describe various situations. Space and shape include recognizing geometric shapes and understanding their basic properties, among other spatial and planar arrangements. Lastly, change and relationships involve understanding functional connections and patterns, which includes recognizing and understanding patterns and proportionality. The test had acceptable reliability (Expected A Posteriori / Plausible Values

(EAP/PV) = .81 and weighted likelihood estimator (WLE = .79; Kock et al., 2020). For the present study, the WLE score was used as a measure of mathematical competence.

Scientific competence (T5, age 7). The framework and conceptualization of scientific competence in the NEPS was developed based on many studies (Hahn et al., 2013). It differentiates between knowledge of science (KOS) and knowledge about science (KAS). KOS comprises content-related components such as matter, development, interactions, and systems, while KAS comprises process-related components such as scientific enquiry and reasoning within the context of scientific literacy in health, environment, and technology. Both KOS and KAS were assessed using one, ten, and nine items, respectively. The test items were embedded in a science and technology game and assessed using a tablet computer. In the game, the children are guided by a little dragon called 'Nepsi' who reads picture-based items and possible solutions to them. It also asks the children to either pick the right answer out of four multiple-choice pictures or to select the right and wrong answer from a larger collection of pictures. Overall, the test comprises 21 items, and the weighted likelihood estimator (WLE) score was used as a measure in this study (ranging from 4.91 to 3.70). The reliability of the WLE estimator was acceptable (EAP/PV reliability = .70; WLE reliability = .67; Hahn, 2021).

Receptive vocabulary (T5, age 7). The children's receptive vocabulary was assessed using a German version of the Peabody Picture Vocabulary Test (PPVT-4; internal consistency as reported by the test authors: α = .97; Dunn & Dunn, 2007; Lenhard et al., 2015). The test instructed the child to select one out of four pictures that matched an auditory presented by the tablet computer. The child first completed a practice session, during which he or she had to correctly answer two out of four items in order to proceed to the test phase. The test phase comprised a total of 19 sets, with each set consisting of 12 items (228 items in total). The sets, which varied in their level of difficulty, were conducted until the child made more than seven mistakes. The highest level of difficulty was recorded. In the study, the sum score indicated by the number of correctly solved items (actual range 0–121) was used as an indicator of receptive vocabulary.

Together, these indicators were included to model a latent academic competence construct, reflecting shared variance across receptive vocabulary, mathematical, and scientific domains, with the composite showing acceptable reliability (ω = .78), when analyzed as a CFA model. In subsequent analyses, these domains were also included separately to capture domain-specific relations.

3.2.4. Control variables

Negative affectivity and surgency (T1 T2, ages 3 and 4**)**. The German version of the Child Behavioral Questionnaire (CBQ-VSF; Putnam & Rothbart, 2006) was used to assess children's negative affectivity (e.g., difficulty in being soothed when upset; α = 66 –.70) and surgency (e.g., enjoyment of rhythmic activities like rocking; α =.70 –76). The parents rated three items per scale on a six-point Likert scale, ranging from 0 (*does not apply*) to 1 (*completely applies*). The reliability scores for negative affectivity and for surgency at age 3 (α = .56, .48) and 4 (α = .62, .54) were low. The correlations for negative affectivity (.50) and surgency (.57) were moderate across ages 3 and 4. Hence, to improve reliability, the scores were averaged across items and waves (negative affectivity α = .66, surgency α = .72).

Home interaction language (T1, age 3**)**. The parents were asked to specify the language mostly spoken at home with the child using the following categories: 1=*only German*, 2=*mostly German, but sometimes also another language*, 3=*mostly another language but sometimes also German*, 4= *only another language*. These categories were then recoded as 0= *language other than German* (23.47%) and Category 1 as 1= *only German* (76.53%) in this study.

Socio-economic status (HISEI, T1, age 3**)**. Parental socio-economic status was assessed using the highest International Socio-Economic Index (HISEI; Ganzeboom & Tremain, 1992). The HISEI is derived from the 2008 International Standard Classification of Occupations (ISEO) and ranks an individual's most recent occupational position based on his or her education and typical earnings in that occupation. For each family, the highest ISEO score among the two parents (i.e., mother and father) was used. In this sample, the HISEI scores ranged from 13.87 to 88.96, with a mean of 61.95 (SD = 20.17). Lower scores (e.g., 13.87) generally correspond to lower-skilled or manual jobs such as cleaners or laborers, while higher scores (e.g., 88.90) reflect high-skilled professions such as physicians, engineers, or legal professionals. Importantly, the sample with respect to HISEI was representatively drawn from the German population (Zinn et al., 2020), although, as with most longitudinal studies, selective dropout occurred. Consequently, the sample underrepresents very low-SES families, but the degree of selectivity may be relatively lower than studies including a more restrictive sample.

Gender (T1, age 3**):** The gender of the child was coded as 0=*male* (49.92%) and 1=*female* (50.08%) and was based on parent-report.

Non-verbal cognitive functioning (T1, age 3**)**. This was assessed using a subtest of the Snijders-Oomen nonverbal intelligence test (SON-R 2 1/2–7; Tellegen et al., 2007) named "categories". The subset measures children's reasoning and abstract thinking abilities, and the task requires the child to recognize connections between abstract concepts or objects and draw conclusions. The test comprised fifteen items divided into two parts as well as an additional practice session to make sure the child understood the instructions before conducting the second part of the test. In the first part (Items 1-7), the child had to sort four out of six pictures according to a specific characteristic. For instance, flowers and candies were grouped together. In the second part of the test (Items 8-15), the child was shown three pictures with a similar characteristic and then asked to choose two pictures with the same characteristics as the three pictures from a larger set of five or more pictures. As the test was implemented as a learning test, the children were provided feedback on their performance after each item. The test ended after three incorrect responses. For the current study, the weighted likelihood estimator (WLE) ranging from −4.05- 6.09 was used as a measure for this construct.

Previous academic competence in the domains of receptive vocabulary (T1 and 3, ages 3 and 5), **mathematics** (T2, age 4), **and science** (T3, age 5). In the NEPS, standardized mean scores for receptive vocabulary at ages 3 and 5 were calculated. Additionally, mathematical competence was assessed at age 4, demonstrating acceptable reliability (EAP/PV = .70; weighted likelihood estimator (WLE = .67; Kock et al., 2020; Petersen & Gerken, 2018). Similarly, scientific competence was assessed at age 5, with sufficient reliability (EAP/PV reliability = .673; WLE reliability = .639; Hahn, 2019). To assess mathematical competence (at age 4) and scientific competence (at age 5), WLE scores were used as measures in this study. These assessments were based on the same competence models but with easier items included. It should be noted that the set standardized scores were only used for receptive vocabulary, whereas WLE scores were used for mathematical and scientific competence.

3.2.5. Assessment of overlaps between self-regulatory facets and behavioral problems

Before the main analyses, exploratory and confirmatory factor analyses (EFA and CFA; Appendices C–D) were conducted to examine whether the self-regulatory facets, particularly parent-reported EC at ages 3 and 4, and the behavioral problem subscales represented distinct constructs. EC was of particular interest because it was assessed via parent report and has a strong theoretical association with behavioral problems, particularly hyperactivity (Eisenberg et al., 2005; Rothbart & Bates, 2006). It was therefore most likely to show some overlap. The EFA results indicated that the behavioral problem subscales did not load onto factors shared with EC, although one hyperactivity item ("thinks before he acts") weakly cross-loaded with an EC item ("is very concentrated while painting or drawing"; loading = –.38, uniqueness = .72). To further validate these findings, a CFA was conducted, which supported a four-factor model comprising related yet distinct constructs and demonstrating a better fit to the data than alternative solutions. Building on these findings, additional exploratory and confirmatory analyses including all self-regulatory facets and hyperactivity (Appendices E–F) were conducted to examine whether similar patterns extended to other facets. These analyses indicated that each facet largely functioned as a distinct construct. Although the factor structure did not align perfectly with a one-, two-, or three-factor solution, minor cross-loadings—particularly between EC and hyperactivity—were observed. Importantly, these cross-loadings were weak and conceptually consistent with the original subscales, likely reflecting developmental variability rather than a lack of distinction between the constructs.

3.3. Data analysis plan

After the preliminary analyses, structural equation modeling (SEM) was conducted to evaluate the hypothesized mediation pathways between self-regulation, behavioral problems, and academic competence. The models were estimated in Mplus 7 (Muthén & Muthén, 2017) using the maximum likelihood estimator with robust standard errors (MLR). Model fit was evaluated with the comparative fit index (CFI $\geq$ .90; Bentler, 1990), the root mean square error of approximation (RMSEA $\leq$ .06; Hu & Bentler, 1999), and the standardized root mean square residual (SRMR $\leq$ .06; Hu & Bentler, 1999). In the sample, the key variables (self-regulatory facets, behavioral problems, and academic competence) exhibited between .78% and 50.23% missing data. Among the covariates, missingness ranged from .83% to 21.54% (see Table 1). To evaluate potential bias, children with $\geq$10% missing data on the predictors, mediators, or outcomes were compared to those with complete data (see Appendix G). Children with missing data on self-regulatory measures generally showed lower scores in receptive vocabulary at age 7, mathematical competence at age 6, scientific competence at age 7, and non-verbal cognitive functioning. Those with missing data on these self-regulatory facets were additionally associated with lower scores in receptive vocabulary at age 3, mathematical competence at age 4, and scientific competence at age 5, alongside other individual covaries specific to the individual facets of self-regulation. Lastly, children with missing behavioral problem data scored significantly lower on non-verbal cognitive functioning, home interaction language, and receptive vocabulary at age 3 compared to children with complete data. Based on these observed differences, missingness was assumed to be missing at random (MAR), and was handled using full information maximum likelihood (FIML).

When accounting for missing data, the main models (Figs. 1–4) analyzed the mediating role of behavioral problems in the relations between self-regulation and academic competence. The analyses were conducted both overall across all academic competence domains and separately for each domain. The overall model captured general patterns, while the domain-specific analyses identified unique pathways and potential differences in how behavioral problems mediate self-regulation for each academic competence domain. Fig. 1 presents the overall model, while Figs. 2–4 display the domain-specific mediation models for mathematical competence (Fig. 2), scientific competence (Fig. 3), and receptive vocabulary (Fig. 4). In all models, the control variables—negative affectivity, surgency, home interaction language, socio-economic background, child's sex, and non-verbal cognitive functioning—were included by regressing both the mediator (behavioral problems) and the academic competence outcomes on these covariates. The self-regulatory facets (independent variables) were allowed to covary to account for their intercorrelations. Early receptive vocabulary at age 3 was included as a control variable in all analyses to adjust for baseline differences. For the models predicting mathematical (Fig. 2) and scientific competence (Fig. 3), receptive vocabulary at age 5 was omitted to avoid over-adjustment, given its potential role in mediating growth between ages 3 and 5. Additionally, in the overall model

Table 1
Descriptive statistics of the study variables (N = 1,931).

Variable	*N*	*M*	*SD*	*Min*	*Max*	*Missing (%)*
Predictor Variables						
(1) Phonological working memory (3y)	961	3.31	2.35	0	10	50.23%
(2) Inhibitory control (4y)	1361	72	.27	0	1	29.52%
(3) Cognitive flexibility (4y)	1259	54	.31	0	1	34.80%
(4) Delay of gratification (3y)	1717	77.93% (child waits)		0	1	11.08%
(5) Parent-reported EC (3-4y)	1915	4.34	.89	0	6	.83%
Mediating variables						
(6) Behavioral problems (5y)	–	01	02 (*S.E*)	–	–	–
Peer relationship problems (5y)	1747	21	27	0	1.6	9.53%
Hyperactivity (5y)	1744	54	39	0	2	9.68%
Conduct problems (5y)	1744	36	28	0	1.8	9.68%
Dependent variables (Academic competence)						
(7) Mathematical competence (6y)	1743	01	1.17	–4.71	4.03	9.74%
(8) Scientific competence (7y)	1916	−01	97	–4.92	3.70	78%
(9) Receptive vocabulary (7y)	1916	143.95	21.38	19	200	78%
Control variables						
(10) Negative Affectivity (3-4y)	1915	3.28	1.01	0	6	83%
(11) Surgency (3-4y)	1915	4.27	95	1	6	83%
(12) Non-verbal cognitive functioning (3y)	1744	259	2.49	–4.055	6.09	9.68%
(13) Home interaction language (3y)	1815	76.53% (Only German)		0	1	6.01%
(14) Socio-economic status (HISEI, 3y)	1515	61.50	20.30	13.87	88.96	21.54%
(15) Child's sex (3y)	1845	50.08% (female)		0	1	4.45%
(16) Receptive vocabulary (3y)	1429	48.39	27.92	0	121	26%
(17) Receptive vocabulary (5y)	1750	107.46	23.16	0	207	9.37
(18) Mathematical competence (4y)	1641	03	1.04	–3.55	3.19	15.02%
(19) Scientific competence (5y)	1748	03	97	–2.96	4.88	9.48%

Note. y = years. Behavioral problems at age 5 were modeled as a latent variable indicated by the subscales peer relationship problems, hyperactivity, and conduct problems.

(Fig. 1), we included a standardized composite score of prior academic competence to parsimoniously control for earlier competence, in addition to the child and family covariates described above. This score was computed as the average of the z-scores for mathematical competence at age 4, scientific competence at age 5, and receptive vocabulary at ages 3 and 5 (intercorrelations r = .34–.46; α = .40). The domain-specific models controlled for prior competence in the respective domains: mathematical competence (at age 4) for Fig. 2, scientific competence (at age 5) for Fig. 3, and receptive vocabulary (at ages 3 and 5) for Fig. 4. In addition, these models also included the child and family covariates described above.

4. Results

4.1. Descriptive statistics and correlations among all study variables

The descriptive statistics and correlations for all study variables are

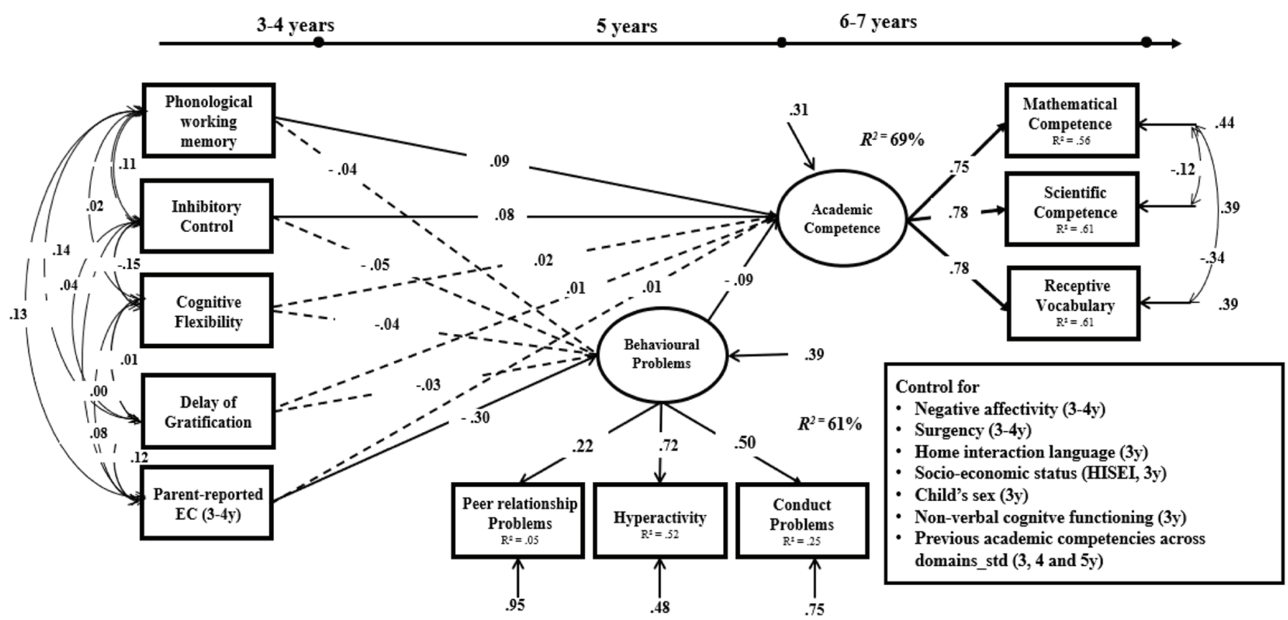

Fig. 1. Results of model with Academic Competence. Significant standardized coefficients are reported in black (p ≤ .05) and insignificant coefficients in dotted lines. N = 1931, CFI = .94, RMSEA = .05, SRMR = .03. N = 1,931.

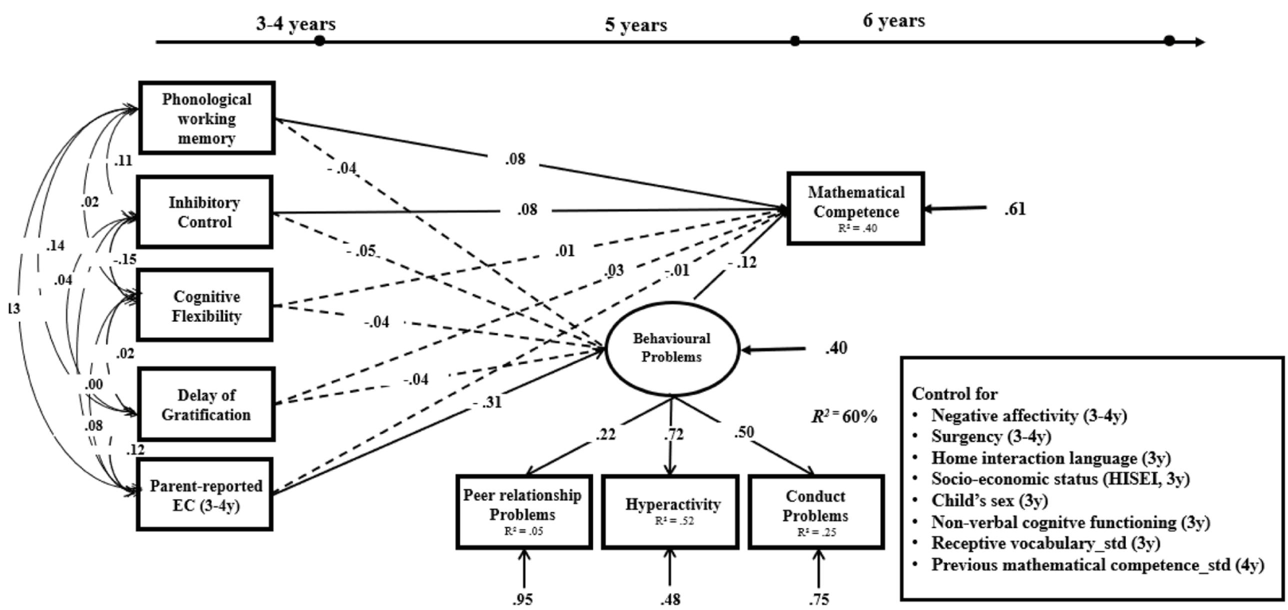

Fig. 2. Results of model with Mathematical Competence. Significant standardized coefficients are reported in black (p ≤ .05) and insignificant coefficients in dotted lines. N = 1931, CFI = .91, RMSEA = .06, SRMR = .02. N = 1,931.

presented in Tables 1 and 2, respectively. The correlations were considered significant at $p < .05$ and were interpreted as effect sizes according to Cohen's (1988) guidelines: $|r|$ = .10 (small), $|r|$ = .30 (moderate), and $|r|$ = .50 (large). Children with better phonological working memory, inhibitory control, and parent-reported EC at ages 3–4 showed small to moderate positive correlations with receptive vocabulary at age 7 (r = .22, .17, .11) and with mathematical (r = .29, .24, .10, at age 6) and scientific competencies (r = .26, .22, .11, at age 7). Additionally, better delay of gratification abilities were positively associated with mathematical (r = .07) and scientific competence (r = .06, at age 6 and 7), with small effect sizes. In contrast, higher levels of behavioral problems at age 5 were negatively correlated with receptive vocabulary at age 7 (r = −.20) and with mathematical (r = −.18, age 6) and scientific competencies (r = −.18), showing small-to-moderate effects. Moreover, phonological working memory (r = −.13), inhibitory control (r = −.09), delay of gratification (r = −.07), and parent-reported EC (r = −.29) showed negative correlations with behavioral problems at age 5. All correlations were based on observed mean scores for each variable.

4.2. Main models

Figs. 1–4 illustrate the mediating role of behavioral problems in the relations between self-regulatory facets and various academic competencies, analyzed overall and in domain-specifical models while accounting for relevant covariates. All models demonstrated an acceptable fit (CFI = .91–.94, RMSEA = .05, SRMR = .02–.03). Across the domains, parent-reported EC consistently predicted behavioral problems (β =

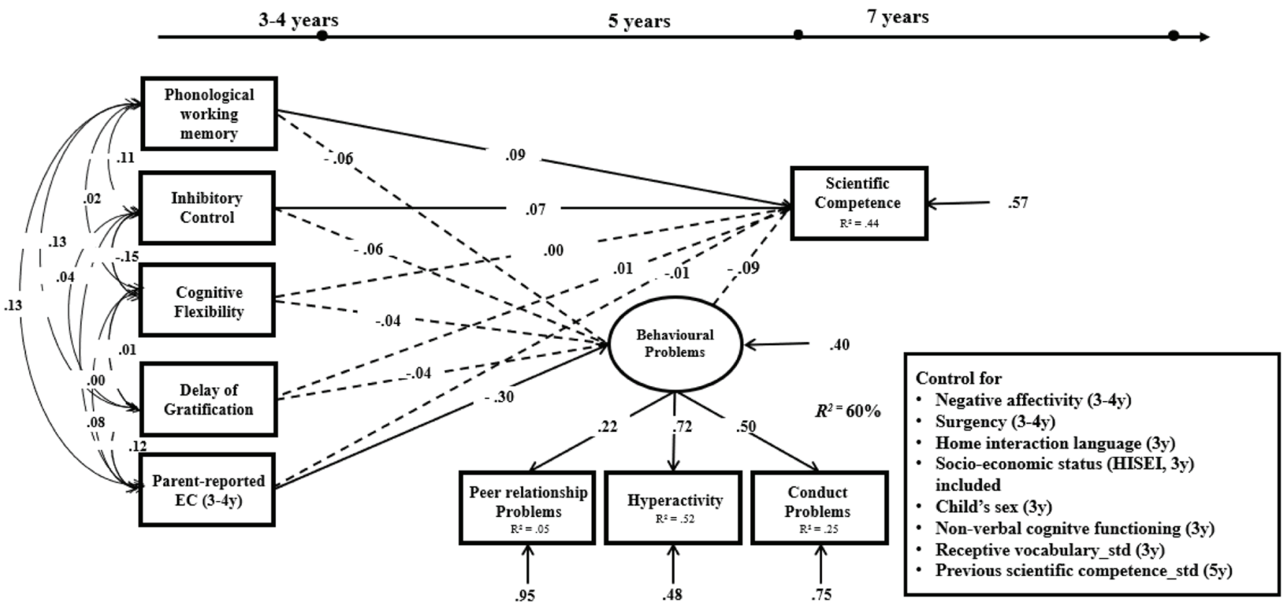

Fig. 3. Results of model with Scientific Competence. Significant standardized coefficients are reported in black (p ≤ .05) and insignificant coefficients in dotted lines. N = 1931, CFI = .93, RMSEA = .05, SRMR = .02. N = 1,931.

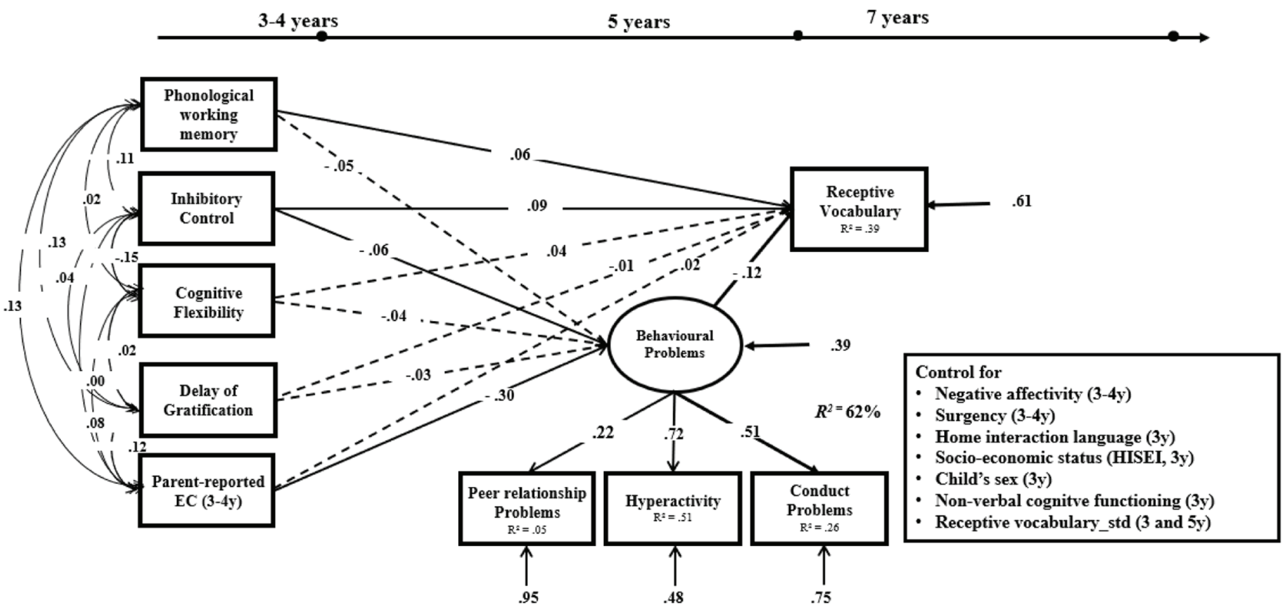

Fig. 4. Results of model with Receptive Vocabulary. Significant standardized coefficients are reported in black (p ≤ .05) and insignificant coefficients in dotted lines. N = 1931, CFI = .92, RMSEA = .05, SRMR = .02. N = 1,931.

–.30 to –.31, $p < .001$, moderate effect), whereas phonological working memory ($\beta = .06$ to .09, $p < .001$, small effect) and inhibitory control ($\beta = .08$ to .09, $p \leq .001$, small effect) generally showed direct positive relations with academic competence. An exception was the receptive vocabulary model (Fig. 4), where inhibitory control predicted both receptive vocabulary ($\beta = .09$, $p < .001$, small effect) and behavioral problems ($\beta = -.06$, $p < .05$, small effect). Behavioral problems negatively predicted most academic competence domains, with small effects for overall academic competence ($\beta = -.09$, $p < .05$), domain-specific mathematical competence ($\beta = -.12$, $p < .05$), and receptive vocabulary ($\beta = -.12$, $p = .05$). In contrast, the association between behavioral problems and scientific competence was not significant ($\beta = -.09$, $p = .08$). Significant indirect effects of parent-reported EC via behavioral problems were observed for the overall academic competence model ($\beta = .03$, $p < .05$), mathematical competence ($\beta = .05$, $p < .05$), and receptive vocabulary ($\beta = .04$, $p = .05$). However, no significant indirect effect was found for scientific competence ($\beta = .03$, $p = .08$).

Overall, the domain-specific models (Figs. 2–4) largely reflected the patterns seen in the overall model (Fig. 1). However, they also highlighted some domain-specific differences: the non-significant relations between behavioral problems and scientific competence (Fig. 3) and the relations of inhibitory control with both behavioral problems and receptive vocabulary (Fig. 4). Because the indirect effects of parent-reported EC on academic competence via behavioral problems were not consistently significant across the three domains (see Table 3 for details), the study could not analyze which of the domains—mathematical, scientific, or receptive vocabulary—exhibited the strongest mediation effect. Accordingly, the three academic

Table 2
Bivariate correlations (Pearson and Point-Biserial) between all study variables (Raw Data).

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1) Phonological working memory (3y)	—																	
(2) Inhibitory control (4y)	.07	—																
(3) Cognitive flexibility (4y)	.02	–.15*	—															
(4) Delay of gratification (3y)	.12*	.03	.02	—														
(5) Parent-reported EC (3-4y)	.12*	.08*	.01	.12*	—													
(6) Behavioral problems (5y)	–.13*	–.09*	–.03	–.07*	–.29*	—												
(7) Mathematical competence (6y)	.29*	.24*	.01	.07*	.10*	–.18*	—											
(8) Scientific competence (7y)	.26*	.22*	.01	.06*	.11*	–.18*	.53*	—										
(9) Receptive vocabulary (7y)	.22*	.17*	.04	.04	.11*	–.20*	.43*	.61*	—									
(10) Negative Affectivity (3-4y)	–.07*	–.03	–.01	.02	–.05*	.37*	–.09*	–.08*	–.05*	—								
(11) Surgency (3-4y)	–.03	–.07*	–.02	–.05*	–.11*	.34*	–.06*	–.08*	–.10*	.25*	—							
(12) Home interaction language (3y)	03	.04	–.01	.03	.04	–.09*	.15*	.20*	.32*	–.01	–.09*	—						
(13) Socio-economic status (HISEI- 3y)	.08*	.08*	.04	.03	.09*	–.23*	.25*	.28*	.29*	–.07*	–.11*	.15*	—					
(14) Child's sex (3y)	–.04	.07*	.03	.11*	.21*	–.15*	–.07*	-.08*	–.16*	–.07*	–.14*	–.04	–.01	—				
(15) Non-verbal cognitive functioning (3y)	.20*	.13*	.02	.06*	.10*	–.15*	.29*	.29*	.21*	–.06*	–.07*	.07*	.09*	.14*	—			
(16) Receptive vocabulary (std 3 and 5y)	.26*	.13*	.03	.10*	.11*	–.17*	.35*	.43*	.50*	–.04	–.08*	.27*	.20*	–.04	.23*	—		
(17) Mathematical competence (4y)	.33*	.29*	.02	.04	.09*	–.17*	.56*	.46*	.36*	–.06*	–.07*	.12*	.19*	.08*	.36*	.34*	—	
(18) Scientific competence (5y)	.22*	.19*	.01	.05*	.13*	–.17*	.47*	.58*	.50*	–.06*	–.08*	.19*	.23*	.04	.25*	.44*	.46*	—

Note. Non-verbal CF = Non-verbal cognitive functioning, HISEI = Highest International Socio-Economic Index (Ganzeboom & Treiman, 1992), y= years. $^*p < .05$. Also note that while bivariate correlations were calculated using the behavioral problems sum score for descriptive purposes, the mediation models employed a latent behavioral problems factor composed of peer problems, conduct problems, and hyperactivity. Because it was not feasible to extract reliable latent factor scores for inclusion in the descriptive table, the simpler sum score was reported instead. Correlations represent effect sizes (Cohen, 1988), with values of $|r| = .10$ considered small, $|r| = .30$ moderate, and $|r| = .50$ large. $N = 1{,}931$.

competence domains were not formally compared. Furthermore, the influence of various control variables in the mediation model are reported in Appendix H.

To account for potential overlap between the self-regulatory facets—particularly parent-reported EC at age 5—and behavioral problems (also at age 5), additional analyses were conducted. These analyses analyzed whether behavioral problems similarly mediated the relations between parent-reported EC at ages 3–4 and academic competence, in the overall and domain-specific models, after controlling for parent-reported EC at age 5 and other relevant variables. The results are presented in Figs. A1–A4 (and in Appendix I). For mathematical competence and receptive vocabulary, the direct and indirect relations identified in the main models (Figs. 1–4) remained statistically significant, although slightly attenuated. Consistent with the main analyses, neither the direct nor indirect effects were significant for scientific competence. In the overall model (Fig. 1), however, the direct association between behavioral problems and academic competence was non-significant ($\beta = -.09$, $p = .07$). Furthermore, the previously significant indirect association between parent-reported EC (ages 3–4) and academic competence via behavioral problems was also no longer significant, suggesting that parent-reported EC at age 5 may partially account for this pathway. Taken together, these results indicate that the overall pattern observed in the main models (Figs. 1–4) was largely robust, with only modest reductions in effect sizes when EC at age 5 was included in the overall model.

5. Discussion

The current study extends prior work and theory (Bronfenbrenner & Morris, 2006; Backer-Grøndahl et al., 2019; Doshi et al., 2024, 2026; Liew et al., 2019, 2020) by analyzing whether behavioral problems at age 5 mediate the association between early self-regulatory facets (ages 3–4) and later academic competence (ages 6–7), while controlling for key variables in the context of the transition from the unstructured preschool to structured primary school context. To address this question, analyses were first conducted using an overall model that included a latent factor of academic competence, followed by domain-specific models for mathematics (age 6), science (age 7), and receptive vocabulary (age 7).

In all models, phonological working memory and inhibitory control were positively related to academic competence across all domains (Figs. 1–4), whereas parent-reported EC was negatively related to behavioral problems (except in Fig. 3). Although this potential differential pattern (based on the proposal that these facets can be distinguished as emotionally neutral EF versus emotion-related) could not be directly analyzed, the results of the present study may be partially suggestive of such a pattern. This is because certain self-regulatory facets (e.g., phonological working memory, inhibitory control) appear to be particularly suited to the demands of conceptual, content-based (or emotionally neutral) contexts, whereas parent-reported EC is more relevant for emotion-related contexts. This pattern aligns with findings from both structured and unstructured preschool settings (Blair et al., 2015; Doshi et al., 2024, 2026; Denham et al., 2012; Kim et al., 2013; Liew, 2012).

With respect to the non-significant associations involving delay of gratification, this pattern may be partly explained by the distribution of the delay of gratification measure. In the present study, 78% of three-year-olds were able to wait for the larger reward, indicating relatively advanced delay abilities at this age. Such ceiling effects may have attenuated associations with behavioral problems and/or academic competence. Finally, regarding cognitive flexibility, it is important to note that much of the existing literature has relied on tasks such as the Dimensional Change Card Sort (DCCS; Zelazo, 2006) to assess this construct in early childhood. Although the switching component of the flanker task used in the present study has been employed in some prior research as an indicator of cognitive flexibility (e.g., Gashaj et al., 2019;

Table 3
Standardized estimates for direct and indirect effects by academic competence.

Effect type	Academic Competence Estimate B (SE)	Mathematical Competence Estimate B (SE)	Scientific Competence Estimate B (SE)	Receptive Vocabulary Estimate B (SE)
Phonological working memory				
Total	10*** (.03)	08* (.03)	10*** (.03)	07* (.03)
Total indirect	00 (.00)	00 (.00)	01 (.01)	01 (.01)
Direct	09*** (.03)	08* (.03)	09*** (.03)	06 (.03)
Inhibitory control				
Total	09*** (.02)	09*** (.02)	08*** (.02)	10*** (.02)
Total indirect	01 (.00)	01 (.01)	01 (.01)	01 (.01)
Direct	08*** (.02)	08*** (.02)	08*** (.02)	09*** (.02)
Cognitive flexibility				
Total	02 (.02)	01 (.03)	01 (.02)	04 (.02)
Total indirect	00 (.00)	01 (.00)	01 (.00)	01 (.01)
Direct	02 (.02)	01 (.03)	01 (.02)	04 (.02)
Delay of gratification				
Total	02 (.02)	03 (.02)	01 (.02)	–.00 (.00)
Total indirect	00 (.00)	00 (.00)	00 (.00)	00 (.00)
Direct	01 (.02)	03 (.02)	01 (.02)	–.01 (.02)
Parent-reported effortful control				
Total	04* (.02)	03 (.02)	02 (.02)	05* (.02)
Total indirect	**03* (.01)**	**05* (.02)**	03 (.02)	**04* (.02)**
Direct	01 (.02)	–.01 (.03)	–.02 (.02)	02 (.03)

Note. *p < .05, **p < .01, **p < .001. N = 1,931.

Oeri & Roebers, 2022), the flanker task is more commonly conceptualized as a measure of inhibitory control (Bauer & Zelazo, 2014; Doshi et al., 2024; Oeri et al., 2018). Accordingly, it remains unclear whether the present findings reflect limitations associated with the specific task employed or genuine associations between cognitive flexibility and the outcomes examined (see also Doshi et al., 2024, 2026).

Aside from these non-significant relations, the findings indicate that behavioral problems mediate the relations between parent-reported EC and academic competence, particularly in the mathematical competence and receptive vocabulary domains, even after accounting for all control variables. This pattern aligns with the study's hypotheses, supporting the mediation frameworks (Eisenberg et al., 2005, 2010; Liew et al., 2019, 2020; Rimm-Kaufman & Pianta, 2000) as well as prior research demonstrating similar mediation processes linking preschool EC to academic competence in the preschool-to-primary school transition, even across varying preschool contexts (Denham et al., 2012; Valiente et al., 2011; Zhou et al., 2010). These results suggest that, irrespective of preschool context, children may rely on their EC abilities to regulate behavior effectively, which in turn supports the development of academic competence upon school entry.

However, what is new in the current findings (and contrary to hypothesis) is the distinction observed between the overall and domain-specific models. The overall model, which comprises the latent academic competence factor (Fig. 1), captures variance shared across all academic domains, reflecting general academic competence. In contrast, the domain-specific models capture variance unique to each domain, which may explain why behavioral problems mediate the relations for mathematical competence and receptive vocabulary, but not for scientific competence. In the domain-specific model for scientific competence (Fig. 3), the exploratory, inquiry-based preschool approach in Germany may reduce the influence of behavioral problems on scientific competence, as children may have more opportunities for self-directed exploration and guided discovery (Wall et al., 2015). Consequently, self-regulatory abilities—such as phonological working memory and inhibitory control—may be more directly associated with conceptual and analytical reasoning in scientific tasks during the preschool-to-primary school transition (Doshi et al., 2024; Trommsdorff, 2009; Wall et al., 2015).

In contrast, mathematical competence and receptive vocabulary appear to rely on children's engagement in social activities, such as cooperative play in situation-oriented or constructive contexts (Rademacher et al., 2022; Wall et al., 2015). In these settings, children benefit from taking turns, persisting at tasks, and participating in classroom interactions—activities that place continuous demands on both EC and social competence. Classrooms that include language-stimulating activities within a social context—as is typical in unstructured preschool settings—further support children with stronger EC, enabling them to grasp key concepts embedded in early mathematical vocabulary. These language-rich exercises often involve counting words, comparison terms, and spatial or relational vocabulary, providing direct opportunities for children with higher EC to improve both mathematical competence and receptive vocabulary (Cadima et al., 2015; Wall et al., 2015). Taken together, these findings suggest that socially based learning may help reduce behavioral problems and act as a mechanism through which parent-reported EC supports these domain-specific academic competencies more strongly than scientific competence. Furthermore, as hypothesized, some child and family characteristics included in the models—non-verbal cognitive functioning, gender, socio-economic status, and prior academic competence—were largely associated with the predictors, mediators, and outcome variables (see Appendix H), underscoring their continued relevance within the mediation framework proposed by Liew et al. (2019).

This mediating pattern is further supported by the stability of most associations, which remained evident even when parent-reported EC at age 5 was included in the models (Figs. A1-A4). The only notable change was that the mediating effect of EC at ages 3–4 on overall academic competence via behavioral problems was no longer significant (Fig. A1). It is possible that parent-reported EC at age 5 captures some of the same variance already represented by EC at ages 3–4, thereby reducing the latter measure's unique contribution to academic competence. This interpretation aligns with research showing age-related improvements in EC during the preschool years (Hongwanishkul et al., 2005; Montroy et al., 2019). As EC develops between ages 3 and 5, it may reduce behavioral problems, which in turn can weaken the influence of EC measured at ages 3–4 on later academic competence once EC at age 5 is accounted for. Nevertheless, the β-weights for the overall academic competence model were relatively close to those reported in the main analyses (Fig. 1), indicating only modest changes in effect size. This suggests that, although some attenuation is evident, the effects of parent-reported EC (at age 5) and the partial cross-sectional overlap between EC and behavioral problems are unlikely to have strongly biased the estimates.

While the mediating links largely prevailed, it should be noted that the conceptual overlap between parent-reported EC and behavioral problems (across all models) may have contributed to the observed partial mediation. Specifically, some hyperactivity items—such as *"easily distractable, unfocused", "thinks before he or she acts"* (reverse-coded), and *"finishes tasks, good concentration span"* (reverse-coded; SDQ,; Goodman, 1997)—tap constructs closely related to inattentive behaviors (Eisenberg et al., 2010; Kim et al., 2013; Willoughby et al., 2011), which are also reflected in the parent-reported EC item *"is very concentrated while painting or drawing"*(CBQ-VSF, Putnam & Rothbart, 2006). Although factor analyses did not indicate substantial cross-loading between any self-regulatory facet and behavioral problem items (Appendix B-F), the shared conceptual variance between EC and behavioral problems, combined with the fact that both measures were reported by the same parent, may have moderately inflated the partial mediation observed in the models.

5.1. *Strengths and limitations*

Nonetheless, the study offers several notable strengths. A key strength lies in the use of a large-scale dataset, which enables a robust examination of whether behavioral problems mediate the relations between various self-regulatory facets and academic competence across mathematical and scientific domains as well as receptive vocabulary. In addition, the study accounts for a comprehensive set of child and family characteristics within the mediation models (Bronfenbrenner & Morris, 2006; Backer-Grøndahl et al., 2019; Eisenberg et al., 2005, 2010; Liew et al., 2019). Another important strength is the examination of both overall and domain-specific academic competence, allowing for a more nuanced understanding of mediation processes across different academic domains. Moreover, to reduce the risk of circularity in the interpretation of effects, efforts were made to minimize conceptual overlap between predictors and mediating variables. Finally, by including scientific competence alongside more general domains such as mathematics and receptive vocabulary, the study demonstrates the generalizability of these mediation pathways across three academic domains during the transition from unstructured preschool to structured primary school environments.

Yet, the study is not without limitations. First, self-regulation, behavioral problems, and academic competence were not assessed consistently across time points (see Appendix A), which limits the examination of reciprocal or bidirectional relations among these constructs. Hence, future research should examine these associations using uniformly assessed time points to determine whether similar mediation effects persist when these constructs are modeled overall and across domains. Second, some subscales—particularly those assessing effortful control and behavioral problems—showed Cronbach's alpha values below the conventional .70 threshold. While the lower reliability of these measures should be taken into account when interpreting the observed relations, it should also be noted that this is a common issue for short-form or developmental measures in large-scale studies, as standard reliability estimates may underestimate scale quality even when all the items are included (Rammstedt & Beierlein, 2014; Sijtsma, 2009). Yet, future research could use longer scales or additional items for these measures. This could also apply to the delay of gratification and cognitive flexibility measure included (Doshi et al., 2024, 2026), wherein future research could benefit from incorporating a broader range of performance-based assessments, to more clearly disentangle the mediating relations.

Third, shared method variance remains a concern, as both parent-reported EC and behavioral problems were obtained from the same reporter. This could have inflated relations due to shared perceptions, halo effects, or reporter bias. The inclusion of EC at age 5 and a comprehensive set of covariates helps reduce this potential bias, but it cannot be fully ruled out. Therefore, the observed partial mediation should be interpreted with caution. Fourth, as stated earlier, the findings—such as the relations between behavioral problems at age 5 and mathematical competence at age 6—likely reflect children's experiences in preschool settings, which typically have less structured curricula. Although analyses of subgroups of children in the first year of primary school were considered, this was not possible due to insufficient sample sizes (Appendix J). Future research should therefore examine whether these associations differ across more structured versus less structured preschool environments. Fifth, while the interaction language is particularly relevant for the majority-language vocabulary (one of the dependent variables) and competence measures (which require some proficiency in the majority language), it is important to note that there were fewer children that spoke "another language than German" in the sample. Hence, future research should examine more diverse samples to capture a broader range of cultural contexts and socio-economic backgrounds.

Finally, preschool- and school-related variables—classroom quality, teacher-child interactions, classroom climate, and instructional practices—are likely to shape the mediating model during the transition to primary school (Cadima et al., 2015; Eisenberg et al., 2005; Liew et al., 2010; 2019; Yang & Purtell, 2023). For instance, better inhibitory control, stronger teacher-child relationships, and lower perceived peer-teacher conflict were associated with better behavioral engagement in preschool. Together with the quality of classroom organization in first grade, these factors predicted both observed and teacher-reported engagement during first grade (Cadima et al., 2015). Although they were not explicitly included in the current models, acknowledging their potential role highlights that mediating relations are shaped not only by individual and family characteristics but also by broader classroom and school contexts. Future research could examine whether these preschool- and school-level factors (across contexts) also moderate or mediate these pathways.

6. Conclusion

While causal conclusions cannot be drawn, the analyses revealed both direct and indirect pathways linking self-regulatory abilities to academic competence during the transition from unstructured preschool to structured primary school, while accounting for relevant covariates. Specifically, phonological working memory and inhibitory control at ages 3–4 showed direct positive associations with academic competence across mathematical, scientific, and receptive vocabulary domains (Figs. 1–4), whereas parent-reported EC was related to academic competence—particularly in mathematical and receptive vocabulary domains—mainly indirectly via behavioral problems (Figs. 1, 2 and 4). These findings highlight the importance of fostering self-regulatory abilities—including phonological working memory, inhibitory control, and EC—during the preschool years. Preschool interventions targeting phonological working memory and inhibitory control (e.g., classroom-based or computerized training) may promote competence development during the preschool-to-primary school transition, enhancing problem solving and critical thinking in mathematics and science, as well as language skills (Doshi et al., 2024; Gropen et al., 2011; Weiland et al., 2014). Moreover, the observed negative relations, although small, between parent-reported EC and behavioral problems suggest that early support for EC may help mitigate behavioral difficulties that interfere with later competence development, particularly in mathematical competence and receptive vocabulary. Such support can be provided through social-emotional learning (SEL) programs targeting EC and social competence (Liew et al., 2019; Valiante et al., 2011; Zhou & Main, 2010). By strengthening EC and reducing behavioral problems, SEL programs may better prepare children for the academic and behavioral demands of formal schooling, facilitating a smoother transition from unstructured preschool to structured primary school.

CRediT authorship contribution statement

Aashna Doshi: Writing – review & editing, Writing – original draft, Validation, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declarations of competing interest

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ecresq.2026.06.002.

Data availability

Data will be made available on request.

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