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The Bidirectional Interplay Between Self-Regulation and Expressive Vocabulary During Toddlerhood

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The interplay between self-regulation related skills and language is well recognized in dynamic theories, but few empirical studies have tested it, especially in toddlers. The current study examines the bidirectional links between self-regulation related skills and expressive vocabulary in a longitudinal study during toddlerhood. Participants were 268 toddlers (M_{age} = 29.6 months, SD = 4.2; 52% boys), mostly of Portuguese nationality, with medium to high sociocultural and economic status, attending private for-profit and nonprofit facilities in Portugal. Self-regulation (executive function and effortful control) and expressive vocabulary were assessed across three assessment waves. Results from cross-lagged panel models suggested bidirectional links between self-regulation and expressive vocabulary across the three assessment waves. These findings add to previous research by taking a first step into establishing the early onset of the intertwined development of these two foundational skills.

Keywords: toddler, self-regulation, expressive vocabulary, bidirectional effects, longitudinal

Toddlerhood is a period of high interindividual variation and rapid acquisitions across several domains of development (Naudeau et al., 2011). Self-regulation and language are two core complex skills that start to develop early in life and both develop rapidly over the toddler period. Despite the conceptual links between these two skills (Blair, 2002; Vygotsky, 1978), few empirical studies have tested the intertwined nature of these skills in the unique period of toddlerhood. Self-regulation can be defined as the ability to deliberately plan and adjust behaviors and emotions to specific settings or situations (Cadima, Verschueren, et al., 2016; McClelland & Cameron, 2012). As an umbrella construct, self-regulation is comprised of several skills related to executive function, such as response inhibition, attention shifting, and working memory in emotionally neutral settings, contexts, and tasks, as well as by several skills related to effortful control, such as inhibitory control, attention control, and attention shifting in emotionally charged situations (Jones et al., 2016). In this study, we approach self-regulation as comprising children's effortful control and executive function related skills, namely working memory and attention shifting.

Children's expressive vocabulary skills, that is, their ability to produce oral language, is a foundational domain of language that develops rapidly during the toddler period and has a key role in setting the stage for children's future learning and development, influencing school-related skills (e.g., National Early Literacy Panel, 2008). Recently, dynamic models of development have argued that skills such as self-regulation and expressive vocabulary are intertwined and play an important role in the development of each other (Fischer & Bidell, 2006). Despite the importance of self-regulation related skills and expressive vocabulary during early years, most empirical studies have focused on the preschool period, leaving a knowledge gap about the intertwined nature of both skills during the toddler period. Building on the dynamic skill theoretical model, the current study intends to address this gap by investigating the bidirectional links between self-regulation and expressive vocabulary in toddlers.

The Dynamic Skill Theoretical Model

The dynamic skill theoretical model places variation in the spotlight, acknowledging that skills show important fluctuations depending on personal characteristics, task configurations, context specificities, and cultural scenarios (Fischer & Bidell, 2006). The authors compare development to the process of constructing a web, with strands being a joint product of the child's interactions with other people, tasks, and the environment (Fischer & Bidell, 2006). In this web, each strand represents one skill that can go in different directions, highlighting the variation in developmental trajectories, whereas connections between strands represent the relations between developing skills (Fischer & Bidell, 2006).

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The core feature of the dynamic skill theory is that it acknowledges the need to analyze developmental patterns in their complexity, suggesting that skills do not develop in isolation or a static fashion, but they rather vary with context and are likely to influence one another across developmental trajectories (Fischer & Bidell, 2006). According to Fischer and Bidell (2006), all developing skills are intertwined with each other, meaning that each skill plays an active and crucial role in the way other skills function and develop. Moreover, skills are in constant motion to adjust and adapt to different circumstances and contexts (Fischer & Bidell, 2006). Recently, McClelland and Cameron (2019) have emphasized the usefulness of calling upon these dynamic frameworks of human development to better understand the complex relations between children's self-regulation related skills and other foundation skills, such as expressive vocabulary.

Specifically, for a toddler to produce words and simple sentences, it is essential that he or she is able to only to hear, differentiate sounds, and link words to their meaning, but also to concentrate and engage in meaningful interactions (National Scientific Council on the Developing Child, 2007). The importance of self-regulation related skills for children's expressive vocabulary is backed up by conceptual underpinnings that pose that skills such as attention focusing and giving adaptive responses to situations by suppressing automatic responses are important for children to make the most out of their learning contexts and to have a more sophisticated vocabulary repertoire (Blair, 2002). On the other hand, for self-regulation related skills to develop, an ongoing interactive concerted process between these specific skills and other developing skills, such as expressive vocabulary, is expected to be in place. Conceptually, this is in agreement with Vygotsky's theory (Vygotsky, 1978), which stated that expressive language could be a valuable cognitive tool for children to successfully regulate their behavior and come up with solutions to a problem. Therefore, in agreement with the dynamic skill theoretical model, self-regulation and expressive language seem to have dynamic influences on one another throughout development. Moreover, empirical studies have suggested that self-regulation is important for children's expressive vocabulary development (e.g., Bohlmann et al., 2015) and that expressive vocabulary is important for self-regulation development as well (e.g., Vallotton & Ayoub, 2011).

The Dynamic Period of Toddlerhood

The toddler period is a dynamic developmental sensitive period from 12 to 36 months that lays the foundations for the intertwined acquisition of progressively more complex skills across several domains (National Scientific Council on the Developing Child, 2007; Naudeau et al., 2011). Research in developmental psychology and neurobiology has shown that brain plasticity is at its peak during toddlerhood when brain circuits are still in the process of wiring and not yet stabilized, which means that this is the ideal timing for building new skills (Knudsen, 2004). Given that the acquisition of more complex skills builds on the acquisition of skills acquired earlier, toddlers' experiences lay the foundations for future development and learning (Knudsen, 2004).

During this period, children experience rapid growth in foundational domains of cognition and behavior (Tager-Flusberg, 2013). For instance, during toddlerhood, children still rely on adults to manage their emotions, but they become progressively more skilled in shifting attention and delaying gratification for brief moments (Murray et al., 2015; Ruff & Rothbart, 1996). At the same time, from infancy to toddlerhood, children move from babbling, pointing, gesturing, and speaking only a few words to forming sentences (Naudeau et al., 2011). Despite the exponential growth that children experience during toddlerhood, toddlers may differ greatly among themselves in the way they perform specific tasks and in the developmental moment that marks the early onset of more mature behaviors (Fischer & Bidell, 2006; Vallotton & Ayoub, 2011). This high interindividual variation in developmental timing can have important implications for children's social relationships and ability to meet and adjust to environmental demands (Bergman et al., 2002).

Self-Regulation and Expressive Vocabulary Development in Toddlerhood

Self-regulation related skills start developing during the first year of life (Diamond, 1988), and have a great stride during the toddler period (Carlson et al., 2004) and throughout preschool (Hughes et al., 2009). There has been intense debate about how to conceptualize and measure self-regulation (Miyake & Friedman, 2012). Many studies have focused on the factor structure of self-regulation in early childhood but provided inconsistent evidence. While some studies show evidence for a unitary model of self-regulation during early childhood (Fuhs & Day, 2011; Hughes et al., 2009; Wiebe et al., 2008, 2011; Willoughby et al., 2010), others reported a two-domain model as the best solution (Lerner & Lonigan, 2014; Miller et al., 2012; Monette et al., 2015; Mulder et al., 2014; Usai et al., 2013). Mixed findings regarding factor structure of self-regulation can be attributed to differences between studies such as the conceptualization of the construct, the sample characteristics (Lee et al., 2013), and the measures used to assess constructs (Lee et al., 2013; Miller et al., 2012). From the above-cited studies, only two were conducted with toddlers (Mulder et al., 2014, 2017). In their 2014 study, Mulder and colleagues reported that a two-factor solution (cool and hot executive functioning factors) showed the best fit to the data. In 2017, a single factor solution was used to represent tasks related to executive functioning. In the current study, we aim to contribute to this discussion by testing these two approaches to conceptualize self-regulation during toddlerhood.

Although the importance of executive functions and effortful control during preschool for child learning and development is widely acknowledged (e.g., Blair & Razza, 2007), how these skills develop and influence other skills in toddlerhood is less understood. Specifically, studies conducted with preschoolers have established that children's self-regulation related skills predict their later expressive vocabulary (e.g., Bohlmann et al., 2015; McClelland et al., 2007). The scarce studies that have focused on toddlers' self-regulation related skills as predictors of language skills suggest that: (a) toddlers with better working memory are more proficient in receptive vocabulary by kindergarten (Fitzpatrick & Pagani, 2012); (b) toddlers with better executive function skills (namely attention shifting and working memory), perform better on emergent literacy tasks by preschool (Mulder et al., 2017); and (c) 2 year-olds with better executive function (namely attention shifting and working memory) and effortful control skills perform better on receptive vocabulary 1 year later (Mulder et al., 2014).

Notwithstanding, in these studies conducted with toddlers, language skills were only measured through receptive vocabulary skills which, although related to expressive vocabulary, undergo specific processes and develop differently. If looking at a typical developmental trajectory, receptive vocabulary precedes expressive vocabulary (Benedict, 1979), with a recent meta-analysis supporting this same trajectory from receptive vocabulary to children's expressive vocabulary (Fisher, 2017). Despite the big spurt in language production during toddlerhood, receptive vocabulary still largely surpasses their expressive skills (Benedict, 1979). Moreover, it is possible that the association between self-regulation related skills and vocabulary differs across studies focusing on receptive or expressive vocabulary. For instance, among two studies conducted with preschoolers with two time points, one concluded that executive functioning skills predicted receptive vocabulary skills (Weiland et al., 2014), and another concluded that executive functioning did not predict receptive and expressive vocabulary, measured as a single latent variable (Fuhs & Day, 2011). To the best of our knowledge, no study has explored the role of toddlers' self-regulation related skills in predicting children's later expressive vocabulary. Therefore, further longitudinal research is needed to clarify the influence of self-regulation related skills on toddlers' expressive vocabulary.

Expressive vocabulary can influence self-regulation as well. Children learn how to solve problems and master their behavior through the internalization of adult modeled speech (Vygotsky, 1978). Several studies have demonstrated the importance of expressive vocabulary for children's later decoding, spelling, reading, mathematics, and executive function, predicting also fewer externalizing and internalizing problems (Bleses et al., 2016; Kuhn et al., 2014; National Early Literacy Panel, 2008). Moreover, toddlers with expressive vocabulary difficulties have a higher chance of falling behind their peers during adolescence on language related academic measures, such as vocabulary and grammar (Rescorla, 2005).

Vallotton and Ayoub (2011) conducted a longitudinal study to analyze which language skills supported the development of self-regulation related skills between 14 and 36 months of age. Results suggested that expressive vocabulary skills at age 2 predicted not only later levels of self-regulation but also its pace of growth (Vallotton & Ayoub, 2011). Such empirical evidence is in tune with Vygotsky's (1978) longstanding theory about the fundamental role of language in the development of self-regulation during childhood. Vygotsky (1978) argued that when children need to control their impulses, plan, and execute possible solutions to a problem, language can be a precious cognitive tool at their service. Caregivers have an essential role in this theory, because they are key facilitators in the process of children's transition from others to self-regulated speech and behavior, by promoting the learning of thought patterns and cultural symbols, particularly words (Vygotsky, 1978).

Bidirectional Interplay Between Self-Regulation and Expressive Vocabulary

Building upon the dynamic skill theoretical model, research with preschoolers has started to focus on the bidirectional interplay between executive function and/or effortful control and expressive vocabulary. Nevertheless, results are mixed: while some studies suggest that expressive vocabulary, measured either as a manifest or latent construct, predicts children's executive function, namely attention shifting and response inhibition (Fuhs & Day, 2011; ten Braak et al., 2019); others demonstrated bidirectional links between children's expressive vocabulary skills and their executive function (Cadima et al., 2019) and effortful control (Bohlmann et al., 2015). For example, a recent study with Portuguese preschoolers directly assessed children's executive function and vocabulary skills, concluding that executive function was a positive predictor of expressive vocabulary, and vice-versa (Cadima et al., 2019). In this study, only the path from executive function to expressive vocabulary held after adding relational processes into the model (Cadima et al., 2019). A longitudinal study conducted in the United States with dual language learners and monolingual children suggested that expressive vocabulary and effortful control skills, namely compliance and executive control, contributed to one another during the preschool years (Bohlmann et al., 2015).

Most studies' designs consisted of only two measurement waves. Previous studies have acknowledged that a longitudinal design with three measurement waves would cast a better understanding of the bidirectional links between self-regulation related skills and language (Bohlmann et al., 2015). To test bidirectional associations across three time points, controlling for children's prior knowledge in each domain, would allow researchers to test if the interplay between domains continues to hold throughout toddlerhood when children's skills continue to develop rapidly (Fuhs et al., 2014). The only study with three measurement waves that investigated the links between effortful control and expressive vocabulary in preschool, comparing monolingual and dual language learners, pointed to bidirectional effects throughout development (Bohlmann et al., 2015). Moreover, in alignment with the dynamic skill theoretical model of development, prior studies have underlined the possibility of meaningful variations in the timing and strength of the relations between self-regulation related skills and expressive vocabulary during preschool. Given the high interindividual variation that characterizes toddlerhood, it seems likely that such variations in timing and strength of the relations between self-regulation related skills and expressive vocabulary skills are even more pronounced during the toddler period. However, the codevelopmental mechanisms and variation in timing and strength of associations between self-regulation related skills and expressive vocabulary during the unique period of toddlerhood remain unclear.

The scarcity of studies analyzing the bidirectional links between self-regulation related skills and expressive vocabulary in toddlers, the high interindividual variation during this period, and the evidence for time-related variability in the associations between these two skills, call out for more research to better understand the mechanisms underlying this codevelopment in the early years of toddlerhood. Our aim is to analyze the bidirectional interplay between the development of expressive vocabulary and self-regulation related skills, namely effortful control and executive function related skills (specifically working memory and attention shifting) during toddlerhood, to answer the overarching question: Do self-regulation related skills and expressive vocabulary skills influence the development of one another during toddlerhood, after controlling for initial levels of both skills? We extend previous studies conducted with preschoolers (Bohlmann et al., 2015), by investigating the early onset of the interplay between self-regulation related skills and expressive vocabulary during toddlerhood. We expect to find evidence for an earlier onset of the bidirectional interplay between self-regulation related skills and expressive vocabulary, but we acknowledge that it is possible to encounter nuances and unique patterns given the specificity of the toddler period and time-related variability of associations between skills.

Method

Participants

This study is part of a wider research project designed to examine the complex relations among activity settings, educator-child interactions, peer interactions, and self-regulation development on crèches. In Portugal, crèches are centered-based licensed day-care provisions that serve children from 4 months to 3 years of age, before preschool entry. To have geographic variability, we selected crèches located in two large urban areas and one rural area in Portugal. Crèches selection followed two criteria: (a) were high quality according to experts' judgment, and (b) met national guidelines regarding structural characteristics such as group size and educators' minimum qualification. In each crèche, participating classrooms served children with 2 years of age, although all classrooms included slightly younger (1-year-old) and older children (3-years-old) as well, depending on their birthdate.

Participating children (n = 268; 52% boys) were on average 29.6 months old (SD = 4.2) at the first wave of data collection, 35.1 months old (SD = 4) at the second wave of data collection, and 40.2 months old (SD = 4) at the third wave of data collection. Table 1 shows descriptive statistics regarding children, educators, and classrooms. Based on recent approaches regarding sample size and power using structural equation modeling (Kim, 2005), the fit index root mean square error of approximation (RMSEA) was used to compute the minimum sample size required to achieve a level of power of .80. For the full cross-lagged panel model the minimum required sample size is 224.85 to achieve a level of power of .80, for α = .05 (Kim, 2005), which is exceeded by our sample size of 268 toddlers.

Children were enrolled in 29 toddler classrooms, distributed in 22 private nonprofit and private for-profit crèches. On average, nine children per classroom were randomly selected to participate in the current study, varying between seven and 10 children selected per classroom. The majority of the children had Portuguese nationality (n = 168; 96%), 2.3% (n = 4) had double nationality, one French nationality, one Brazilian nationality, and one Angolan nationality (.6% each). Regarding mother's education level, 23.3% (n = 53) attended high school or less and 76.7% (n = 174) had a higher education degree. The majority of mothers worked outside the home (n = 195; 86.3%). Participating educators were the classroom lead educators (n = 29). All were women, with an average age of 38.3 years (SD = 7.6) and an average teaching experience of 12.6 years (SD = 5.9). The majority of the educators had a bachelor's degree (n = 18; 66.7%), and the remaining had a master's degree (n = 9; 33.3%) in early childhood education. The classroom's group size ranged from eight to 22 children, with an average of 16 children enrolled per classroom (SD = 3.1).

Measures

Self-Regulation

To assess self-regulation we used two measures of executive function (attention shifting and working memory) and one measure of effortful control. To assess attention shifting, we used the task Visual Attention from the Developmental Neuropsychological Assessment NEPSY (Korkman et al., 1998). The task is comprised of two trials. In each trial, children are asked to search and stamp targets (bunnies in the first trial and cats in the second) as quickly as possible among several distracting pictures of other animals, humans, toys, and other objects. The time limit is 3 min for each trial. This task is preceded by a practice trial where children use the stamp freely on an empty sheet of paper. The number of correct items and incorrect items is counted for each trial. Final scores were calculated by subtracting the mean of incorrect answers for both trials from the mean of correct answers for both trials. The task has shown good psychometric properties with preschoolers (Visu-Petra et al., 2012). The Selective Attention task of the NEPSY has recently been shown to be a promising measure to assess toddlers' attention shifting (Salminen et al., 2021). When the child refused to collaborate and/or when it was unclear for the assessor if the child understood the instructions, items were coded as missing values. In this sample, skewness values were −.38, −.46, and −1.47, and kurtosis values were .93, .09, and 1.75 at Waves 1, 2, and 3, respectively, acceptable values according to suggested clear-cut standards of skewness ≤ 3 and kurtosis ≤ 10 (Kline, 2016). Mean showed progression from Wave 1 to Wave 2

Table 1
Descriptive Statistics for Child, Educator, and Classroom Demographics

Variable	M	SD	Minimum	Maximum	N
Child characteristics					268
Age (months)	29.63	4.18	16	47	
Educator characteristics					29
Age (years)[a]	38.31	7.64	24	54	
Experience (years)[b]	12.62	5.92	2	24	
Classroom characteristics					29
Group size[c]	16	3	8	22	
Number of adults[c]	2.14	0.65	1	4	

[a] Educators' age in years based on 26 responses to questionnaires. [b] Educators' working experience in early childhood and care based on 21 responses to questionnaires. [c] Number of children enrolled in the classroom, and number of adults responsible for the classroom, based on 28 responses to questionnaires.

and from Wave 2 to Wave 3, with standard deviation, range, minimum and maximum values indicating enough variation in the current sample for this task across all measurement waves (cf. Table 2). There was no evidence of ceiling or floor effects: in Waves 1, 2, and 3, respectively, .4% of children scored the minimum and .4%, .4%, and 1.1% the maximum recorded value.

To measure working memory we used the Hidden Boxes Task (Mulder et al., 2014). In this task, the child is requested to find six wooden toys hidden inside blue boxes. First, the examiner hides six wooden animals inside six identical blue boxes displayed on a board. The examiner asks the child to uncover the blue boxes and find all the animals, one at a time. Each time the child finds an animal, it is removed and the box is left empty. Between each trial, the child is distracted for 6 s. The task is preceded by two practice trials with two boxes and two toys. The test is composed of six items, and each item is coded as 1 if the child is able to find one animal, and 0 if the child fails to do so by opening a box that was already empty. The maximum possible score in this task is 6. The task has been specifically designed to assess working memory in very young children, showing good reliability with toddlers (Mulder et al., 2014). When the child refused to collaborate and/or when it was unclear for the assessor if the child understood the instructions, items were coded as missing values. In this sample, skewness values were −.19, −.36, and −.87, and kurtosis values were −.49, −.52, and .08 at Waves 1, 2, and 3, respectively, acceptable values according to suggested clear-cut standards (Kline, 2016). Standard deviation, range, minimum, and maximum values indicated enough variation in the current sample for this task across all measurement waves (cf. Table 2).

To tap into effortful control, we used the Toy Wrap task from the Preschool Self-Regulation Assessment (PSRA; Smith-Donald et al., 2007). In this task, the researcher asks the child to look away and not peek while the researcher wrapped a surprise to play with the child. The researcher records the child's latency to peek (number of seconds) while the gift is being wrapped. The time limit is 60 s, and a score of 60 s was assigned to children who did not peek. This task has been previously used in Portugal and has shown good psychometric properties (e.g., Cadima, Enrico, et al., 2016). Although the task is usually applied for children from age 3 onward, research has already indicated its validity among samples of toddlers (Carlson, 2005; Caughy et al., 2013; Kochanska et al., 2000). When the child refused to collaborate and/or when it was unclear for the assessor if the child understood the instructions, items were coded as missing values. In this sample, skewness values were 1.81, .54, and −.17, and kurtosis values were 2.20, −1.25, and −1.68 at Waves 1, 2, and 3, respectively, acceptable values according to suggested clear-cut standards (Kline, 2016). Mean showed progression from Wave 1 to Wave 2 and from Wave 2 to Wave 3, with standard deviation, range, minimum and maximum values indicating enough variation in the current sample for this task across all measurement waves (cf. Table 2). There was no evidence of floor effects: in Waves 1, 2, and 3, respectively, 3.4%, 1.5%, and 1.1% of children scored the minimum recorded value.

Expressive Vocabulary

Expressive vocabulary was assessed with one task from the Griffiths Language subscale (Griffiths, 2007). In this task, children are asked to name 20 pictures depicting objects and animals (e.g., spoon, bed, and cup). Pictures are presented in small cards, one at a time. A score of 1 was assigned to correct answers and a score of 0 to incorrect answers, resulting in a maximum possible score of 20. Griffiths is a widely known and used measure of development with good reliability for this age group (e.g., Griffiths, 1996).

Procedure

The current study was approved by the Portuguese National Commission of Data Protection (Project Quality Matters; Portuguese Foundation for Science and Technology; Grant PTDC/MHCCED/5913/2014). Crèches directors, educators, and parents were asked to give their informed consent by signing consent letters that contained detailed information about the project goals and methods. Participant children's parents returned their informed consent letters agreeing with their children's participation in the current study. Child assessments occurred in three waves. The first wave occurred in Fall (between October and December 2016), the second in Spring (between May and July 2017), and the third in Fall of the following school year (between October and December 2017). Approximately 171 days elapsed between the first and second waves of data collection and approximately 154 days elapsed between the second and third waves of data collection. Assessing

Table 2
Descriptive Statistics for Self-Regulation and Language Measures

Variable	*M*	*SD*	Minimum	Maximum	Skew	Kurtosis	*N* (% complete)
Self-regulation							
Attention shifting Wave 1	−2.64	15.22	−56	34	−0.38	0.93	250 (93.28%)
Attention shifting Wave 2	10.59	12.80	−32	36	−0.46	0.09	250 (93.28%)
Attention Shifting Wave 3	21.86	14.06	−29	39	−1.47	1.75	213 (79.48%)
Working memory Wave 1	4.22	1.06	1	6	−0.19	−0.49	252 (94.03%)
Working memory Wave 2	4.96	0.82	3	6	−0.36	−0.52	249 (92.91%)
Working memory Wave 3	5.35	0.74	3	6	−0.87	0.08	212 (79.10%)
Effortful control Wave 1	13.71	17.24	0	60	1.81	2.20	249 (92.91%)
Effortful control Wave 2	25.02	22.00	0	60	0.54	−1.25	245 (91.42%)
Effortful control Wave 3	35.47	23.44	0	60	−0.17	−1.68	210 (78.36%)
Expressive vocabulary							
Expressive vocabulary Wave 1	10.46	4.03	0	18	−0.77	0.27	219 (81.72%)
Expressive vocabulary Wave 2	12.82	3.06	0	19	−1.68	3.81	248 (92.54%)
Expressive vocabulary Wave 3	14.78	2.40	5	19	−1.31	2.57	212 (79.10%)

toddlers within this short time frame increases the possibilities of capturing change and of unveiling the specificities of the toddler period, which is of great value to plan early and targeted interventions (Cole, 2006; Masten et al., 2005).

To check the adequacy of the overall study procedures, the assessment protocol was piloted with two children before data collection beginning. The first evaluations were conducted by two team members; later, two additional team members were trained to further aid with data collection when necessary. When a child's answer or behavior raised doubts, team members would make detailed notes and later discuss such cases as a team. Assessments were conducted in a quiet room located in crèches. Each assessment lasted for approximately 25 min and was usually completed in a single session. Measures were presented in a fixed order that could vary to ensure child participation. In Waves 1 and 2, the tasks were presented in the following order: Toy Wrap Task; Hidden Boxes Task; NEPSY Selective Attention Task; Griffiths Language Subscale Task. In Wave 3, the tasks were presented in the following order: Hidden Boxes Task; NEPSY Selective Attention Task; Griffiths Language Subscale Task; Toy Wrap Task.

Data Analysis

To answer our research question, we conducted analyses in two steps. We first conducted confirmatory factor analysis (CFA) to determine the factor structure of tasks assessing self-regulation (attention shifting, working memory, and effortful control). The latent factor solution was then tested for longitudinal measurement invariance across the three time points (Millsap, 2011; Newsom, 2015). For our purposes, achieving longitudinal metric invariance suffices, because it allows us to compare factor covariances or unstandardized regression coefficients (but not latent means; Little, 2013). To assume metric invariance, this model should fit the data well, and should not represent a large model deterioration in comparison to the freely estimated model. The Satorra-Bentler chi-square difference test (Satorra & Bentler, 2010) and the change in fit indexes such as the comparative fit index (CFI) and root mean square error of approximation (RMSEA; Chen, 2007) were used to test metric invariance. We used the cut-off criteria proposed by Hu and Bentler (1999) to assess model fit, analyzing the chi-square test, the CFI $>$ .90, the RMSEA $<$ .05, and standardized root mean square residual standardized root mean square residual (SRMR) $<$ .08.

Second, to address our main goal we tested bidirectional effects using autoregressive cross-lagged regression models (Kline, 2016). Cross-lagged regression models are the most typical modeling approach to take into consideration the longitudinal nature of the data and the reciprocal nature of developmental processes (Hamaker et al., 2015). Although there has been some recent critiques to the cross-lagged regression models (Hamaker et al., 2015), they offer several advantages, namely, the parameters obtained using these models are adequated for studying the interactions and reciprocal influences between constructs over time, allowing to estimate directionality and temporal precedence (Biesanz, 2012; Hamaker et al., 2015). Also, the inclusion of autoregressive paths allows the control for construct stability, making it an appealing modeling approach (Hamaker et al., 2015). To determine which model best represented the associations between self-regulation and expressive vocabulary we estimated a series of conditional models (with no cross-lagged, unidirectional, and bidirectional models). As depicted in Figure 1, Model 1 represents no lagged associations, Model 2 represents unidirectional associations with self-regulation predicting expressive vocabulary, Model 3 represents unidirectional associations with expressive vocabulary predicting self-regulation and, finally, Model 4 represents the full cross-lagged bidirectional model. Final models were estimated constraining lagged and autoregressive parameters to be invariant over time, controlling for child age and sex. Because children were nested in classrooms, the intraclass correlation coefficient (ICC) was computed to check the proportion of variance at the classroom level for each outcome. ICCs ranged from .00 to .12 for self-regulation measures and from .03 to .09 for expressive vocabulary across the three time points, pointing to minimal classroom-level variance in children's self-regulation and expressive vocabulary skills. All models were computed with M*plus* (Muthén & Muthén, 1998–2012) using the MLR estimator, which is robust to nonnormality. Consequently, the Satorra–Bentler scaled test was used to testing chi-square differences and to compare model fit (Satorra & Bentler, 2010).

Self-regulation measures had approximately 6% to 7% of missing data at Wave 1, 7% to 9% at Wave 2, and 21% to 22% at Wave 3. Expressive vocabulary had approximately 18% missing data at Wave1, 8% at Wave 2, and 21% at Wave 3. Bivariate correlations indicated that expressive vocabulary missing data at Wave 1 was related to child age (r = −.21, p = .001). To avoid possible bias, we included child age in the analysis (Collins et al., 2001; Enders, 2010). Analysis of the remaining missing data patterns suggests that data were missing mainly due to attrition. Bivariate correlations indicated that missingness on all self-regulation measures at Wave 3 were negatively related to child age (working memory: r = −.13, p = .033; attention shifting: r = −.12, p = .043; effortful control: r = −.13, p = .040). Little's MCAR test was not significant, suggesting that self-regulation data were missing completely at random, $\chi^2(4) = 8.759$, p = .067. To handle missing data, we used the full information maximum-likelihood estimation (FIML; Enders & Bandalos, 2001). With FIML, parameters are estimated with all available information, preventing sample size reduction and consequently increasing statistical power (Enders & Bandalos, 2001). This study is not preregistered. More information about the current study data and materials is available upon request.

Results

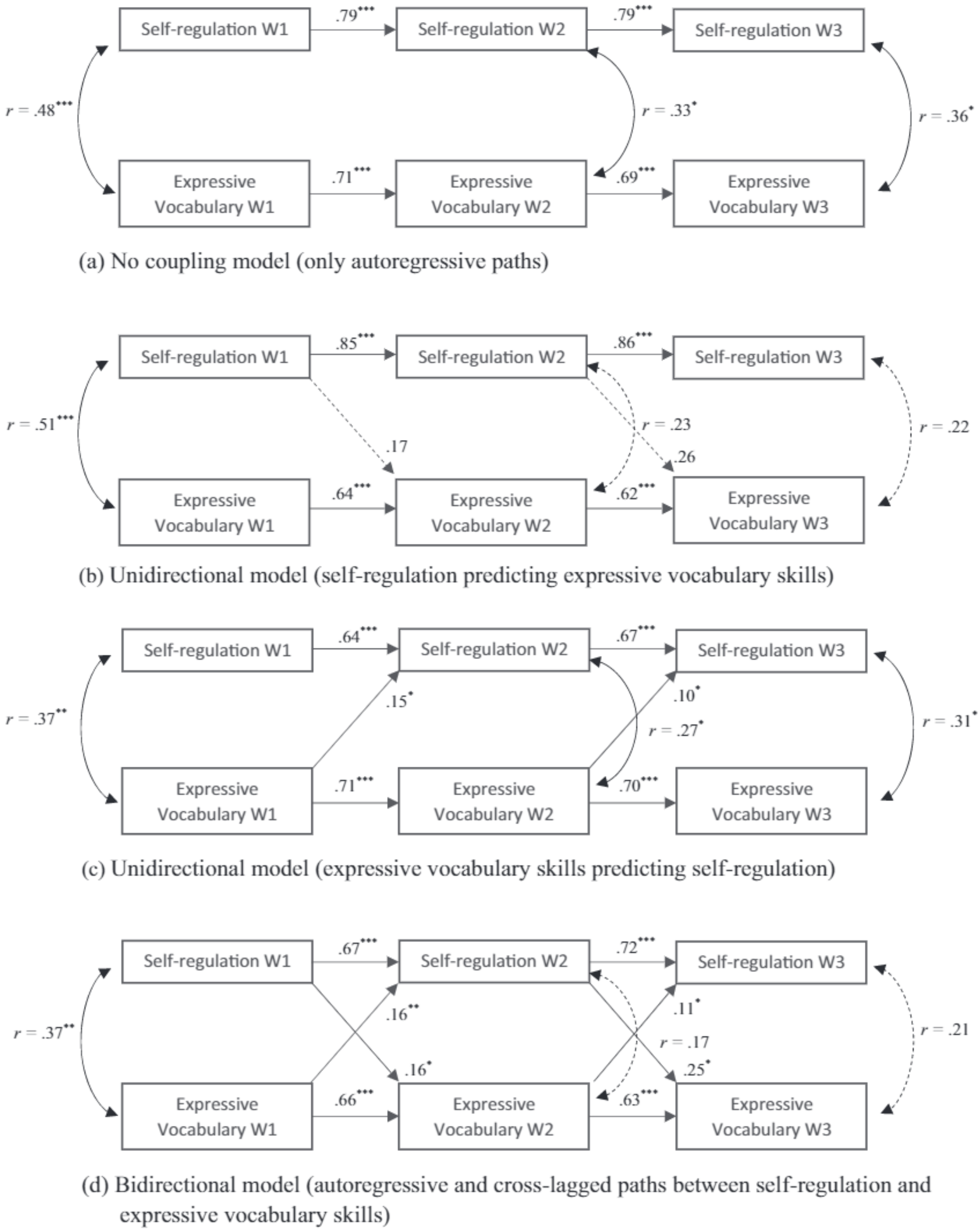
Preliminary Analysis

Simple correlations are presented in Table 3. Older children performed better on all self-regulation and language tasks across the three time points. Girls received higher scores than boys on attention shifting at Wave 1 (r = −.13, p = .048) and Wave 2 (r = −.13, p = .035), and also on effortful control at Wave 2 (r = −.19, p = .002) and Wave 3 (r = −.26, p $<$ .001). As expected, measures were correlated across time points. Moreover, expressive vocabulary measures were correlated with all self-regulation measures, except for working memory at Wave 2.

First, we tested the factor structure of self-regulation, by comparing a two-factor solution with a single factor solution. The

Figure 1

Summary of the Four Estimated Models of Associations Between Self-Regulation and Expressive Vocabulary, Controlling for Child Age and Sex, Across Three Assessment Waves in Toddlerhood



Note. Standardized coefficients are displayed. Dotted lines represent nonsignificant paths. W = wave.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 3
Pearson Correlations for Child Age, Sex, and Measures of Self-Regulation and Language

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Age	—													
2. Sex	.01	—												
3. Attention shifting Wave 1	.36***	−.13*	—											
4. Attention shifting Wave 2	.47***	−.13*	.41***	—										
5. Attention shifting Wave 3	.44***	−.01	.28***	.52***	—									
6. Working memory Wave 1	.37***	−.09	.27***	.30***	.33***	—								
7. Working memory Wave 2	.18**	−.11	.14*	.21**	.26***	.20**	—							
8. Working memory Wave 3	.25***	−.09	.18*	.23**	.31***	.22**	.23**	—						
9. Effortful control Wave 1	.27***	−.04	.37***	.27***	.26***	.23***	.08	.14*	—					
10. Effortful control Wave 2	.32***	−.19**	.43***	.44***	.37***	.27***	.13	.21**	.39***	—				
11. Effortful control Wave 3	.31***	−.26***	.37***	.34***	.36***	.23**	.14	.22**	.35***	.34***	—			
12. Expressive vocabulary Wave 1	.32***	.01	.33***	.36***	.33***	.20**	.01	.14	.25***	.26***	.27***	—		
13. Expressive vocabulary Wave 2	.32***	.02	.20**	.34***	.32***	.18**	.08	.23**	.25***	.26***	.34***	.58***	—	
14. Expressive vocabulary Wave 3	.25***	.01	.23**	.35***	.39***	.20**	.03	.20**	.23**	.19**	.33***	.55***	.72***	—

* Correlation is significant at the .05 level (two-tailed). ** Correlation is significant at the .01 level (two-tailed). *** Correlation is significant at the .001 level (two-tailed).

latent factor solution, $\chi^2(15) = 10.316$, $p = .799$; CFI = 1.00; RMSEA = .000; SRMR = .025, showed a significantly better fit to the data, compared with the two-factor solution, $\chi^2(21) = 100.613$, $p < .000$; CFI = .783; RMSEA = .119; SRMR = .353. Thus, a single construct was created for self-regulation for each of the three measurement waves. CFA factor loadings for attention shifting were .68, .86, and .71, for working memory were .41, .25, and .45, and for effortful control were .55, .51, and .51 for Waves 1, 2, and 3, respectively. Model fit information is not presented because all confirmatory factor models were saturated. We then tested whether the same factor structure for self-regulation was invariant across time, with attention shifting, working memory, and effortful control serving as indicators of the underlying self-regulation skill in the three measurement waves. To do so, we computed three progressively constrained models. In the first model (configural invariance), no constraints were imposed to factor loadings or intercepts. In the second model (metric invariance), equality constraints were imposed to factor loadings in the three measurement waves. In the third model (scalar invariance), equality constraints were imposed to factor loadings and intercepts in the three measurement waves.

As shown in Table 4, the unconstrained model fitted the data well, $\chi^2(15) = 10.316$, $p = .799$; CFI = 1.00; RMSEA = .000; SRMR = .025. Despite the full metric invariance model showed a good fit to the data, $\chi^2(21) = 33.441$, $p = .042$; CFI = .966; RMSEA = .047; SRMR = .069, the Satorra-Bentler chi-square difference test (SBχ^2) was significant, which, along with the analysis of the changes in fit indices such as CFI and RMSEA, prevented us from assuming full metric invariance. Following recent studies indicating that assuming partial metric invariance does not have important effects on the accuracy of analysis and yields accurate and nonbiased estimates (Hsiao & Lai, 2018; Rudnev et al., 2018; Steinmetz, 2013), partial metric invariance was tested by removing the imposed constraints on the loading of effortful control. The difference in the Satorra-Bentler chi-square difference test comparing the partial metric invariance and the configural invariance models was not significant, and differences in CFI and RMSEA were smaller than .01 and .015, respectively. Thus, the partial metric invariance model was equivalent to the configural invariance model and, therefore, partial metric invariance was met, $\chi^2(19) = 19.629$, $p = .417$; CFI = .998; RMSEA = .011; SRMR = .056.

Cross-Lagged Panel Model

Model fit information and chi-square difference tests are presented in Table 5 for the four estimated models. The bidirectional model was the estimated model that best represented associations between self-regulation and expressive vocabulary during toddlerhood because it had the best fit to the data and had a significant improvement over Model 2, $\Delta\chi^2$SB (1) = 42.42, $p < .001$, and Model 3, $\Delta\chi^2$SB (1) = 4.46, $p = .035$. Results from the bidirectional model (Figure 1d) showed that all autoregressive paths were significant, suggesting that children's prior skills significantly and positively predicted later skills in the same developmental domain. Moreover, cross-lagged paths

Table 4
Summary of Measurement Invariance Fit Indexes of a One-Factor Model of Toddlers' Self-Regulation

Measurement invariance	χ^2	*df*	*p*	CFI	RMSEA	SRMR	$\Delta\chi^2$ (*df*)[a]
Configural: Unconstrained	10.316	15	.799	1.00	.000	.025	
Metric invariance: Constrained factor loadings	33.441	21	.042	.966	.047	.069	20.89 (6)**
Partial metric invariance	19.629	19	.417	.998	.011	.056	8.24 (4)
Scalar invariance: Constrained factor loadings and intercepts	392.986	25	.000	.000	.234	.438	325.89 (4)***
Partial scalar invariance	415.078	25	.000	.000	.241	.362	374.34 (6)***

Note. CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.
[a] Chi-square difference test results based on Satorra-Bentler scaling correction.
** $p < .01$. *** $p < .001$.

Table 5
Model Fit Results and Chi-Square Difference Test for the Four Estimated Models, Controlling for Child Age and Sex

Four estimated models	$\chi^2(df)$	CFI	RMSEA	SRMR	$\Delta\chi^2$SB $(df)^a$
Model 1: No coupling	114.453 (59)***	.930	.059	.077	
Model 2: Unidirectional (Self-regulation -> Expressive Vocabulary)	109.528 (58)***	.935	.058	.073	
Difference between Model 2 and 1					3.36 (1)
Model 3: Unidirectional(Expressive Vocabulary -> Self-regulation)	109.409 (58)***	.936	.058	.074	
Difference between Model 3 and 1					8.63 (1)**
Model 4: Bidirectional	103.127 (57)***	.942	.055	.071	
Difference between Model 4 and 2					42.42 (1)***
Difference between Model 4 and 3					4.46 (1)*

Note. CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.
[a] Chi-square difference test results based on Satorra-Bentler scaling correction.
* $p < .05$. ** $p < .01$. *** $p < .001$.

indicated that self-regulation was a significant predictor of expressive vocabulary across the three assessment waves, after controlling for age and sex. Self-regulation at Wave 1 predicted expressive vocabulary at Wave 2, $\beta = .16$, $SE = .08$, $p = .048$, and self-regulation at Wave 2 predicted expressive vocabulary at Wave 3, $\beta = .25$, $SE = .12$, $p = .034$, after controlling for age and sex. Expressive vocabulary at Wave 1 predicted self-regulation at Wave 2, $\beta = .16$, $SE = .06$, $p = .009$, and expressive vocabulary at Wave 2 predicted self-regulation at Wave 3, $\beta = .11$, $SE = .04$, $p = .014$, after controlling for age and sex.

Discussion

The current study aimed to investigate the interplay between self-regulation and expressive vocabulary skills in toddlerhood, an understudied period of rapid development and high interindividual variability. To the best of our knowledge, this is the first longitudinal study that focuses on the interplay between self-regulation and expressive vocabulary during toddlerhood. Overall, findings from cross-lagged panel models with three waves of assessment, when children were 29, 35, and 40 months old, showed bidirectional associations between self-regulation and expressive vocabulary across toddlerhood, which is aligned with the dynamic skill theory of development (Fischer & Bidell, 2006).

More specifically, children who started with better self-regulation at the age of 29 months showed greater expressive vocabulary skills across all measurement waves. Children with higher expressive vocabulary skills at 29 months also showed better self-regulation across all measurement waves. These findings support the idea of a bidirectional interplay between self-regulation and expressive vocabulary, which is in agreement with Bohlmann et al.'s (2015) longitudinal study conducted with preschoolers. Moreover, findings are also aligned with Cadima et al. (2019) that, to our knowledge, is the only Portuguese study investigating the reciprocal associations between executive function and children's expressive vocabulary during the preschool year. Our findings add to these previous studies by indicating that the bidirectional interplay between these two skills starts very early when children start experiencing a growth spurt in their expressive vocabulary and self-regulation related skills. Taken together, our findings add to current evidence suggesting that self-regulation and expressive vocabulary are intertwined and each one seems to play a key role in the functioning and development of each other during early childhood (Fischer & Bidell, 2006).

The results of this study indicate that self-regulation can play an important role in the acquisition of toddlers' expressive vocabulary skills. Our results extend prior research with toddlers that linked self-regulation related skills to receptive vocabulary (Fitzpatrick & Pagani, 2012; Mulder et al., 2014), by pointing to the importance of self-regulation related skills not only for children's ability to understand speech but also, and importantly, for their ability to produce accurate words in response to specific vocabulary prompts. Furthermore, it adds to previous research by indicating the intertwined, more than unidirectional, nature of both skills.

Results also showed that expressive vocabulary is important for self-regulation across toddlerhood. Our findings are aligned with previous literature indicating that toddlers' expressive vocabulary is linked with their self-regulation related skills (Kuhn et al., 2014; Vallotton & Ayoub, 2011). Furthermore, the cross-lagged design of the current study allows expanding previous literature by demonstrating that the association is not unidirectional, but that bidirectional influences between expressive vocabulary and self-regulation skills are already in place during the toddler period.

Findings from the current study point out the possibility that producing words can be particularly important in helping children to regulate their actions early in development, which further supports Vygotsky's theory (Vygotsky, 1978) claiming that language can help regulate children's behavior through the internalization of caregiver's regulatory speech. Toddlers are often encouraged to use their words to express feelings and desires (Vallotton & Ayoub, 2011), which, along with adults' language input, models how children can regulate their emotions and behaviors through language (Zelazo, 2003). Through self-speech, children move from depending mainly on coregulation mechanisms to being progressively less dependent on adults to regulate (Murray et al., 2015). Children internalize words and understand, by interacting with adults that use and encourage them to use vocabulary, that self-speech can help them to think and solve problems, to become aware of one's emotional state, and to regulate emotions and behaviors in different situations (Zelazo, 2003).

On an important note, metric longitudinal invariance for self-regulation did not hold for the current sample. Nonetheless, partial metric invariance was achieved, which according to several authors is a trustworthy solution when constructs are noninvariant over time (Hsiao & Lai, 2018; Rudnev et al., 2018; Steinmetz, 2013). Putnick and Bornstein (2016) have argued that on some occasions longitudinal noninvariance is to be expected because as children develop, their newly and previously acquired skills can be frequently reorganized to accommodate the integration of recent knowledge. Longitudinal noninvariance can also be related to the high interindividual variation that is associated with the period of toddlerhood, with children acquiring skills rapidly, but in their own timing and pace (Fischer & Bidell, 2006; Vallotton & Ayoub, 2011).

Moreover, even though our results suggesting bidirectional patterns are aligned with prior research in preschool (e.g., Bohlmann et al., 2015; Cadima et al., 2019), it is important to note the underlying components of self-regulation in each of these studies. In the present study, self-regulation is measured as a latent variable representing children's executive function (attention shifting and working memory) and effortful control, while Bohlmann et al. (2015) measured preschoolers' effortful control and Cadima et al. (2019) measured preschoolers' executive function skills. Even though studies suggest that self-regulation in the early ages is not yet totally differentiated and can be considered a broad and complex unitary competence (e.g., Wiebe et al., 2008, 2011), more attention is needed to which specific components of self-regulation are investigated in the studies. There have been recent calls for researchers to strive to be more precise about the aspects of regulation related skills under investigation. Moving toward a greater specificity would not only enhance advancements in the field by facilitating a more accurate interpretation of each study's findings but also allow policymakers and teachers to grasp which specific skills are crucial, ultimately leading to more targeted and better designed interventions (Jones et al., 2016).

An additional note relates to task impurity. According to Friedman and Miyake (2017), research studying self-regulation across the life span must deal with the so-called task impurity issue given the nature of the tasks used to assess self-regulation related skills. This happens because self-regulation related skills rely on other cognitive processes, such as language, and, thus, tasks measuring self-regulation related skills unavoidably implicate cognitive processes that differ from the targeted self-regulation skills (Friedman & Miyake, 2017; Miyake et al., 2000). This means that skills such as language ability, among others, can introduce random noise in the data and enhance measurement error and variance not related to targeted self-regulation related skills. In the present study, tasks selected to measure self-regulation did require children to understand what was expected of them but were chosen carefully given the participants' age avoiding, for instance, any request for children to produce language. Still, it would be valuable for the field that future research focuses on the study and development of measures for toddlers, particularly given the fact that toddlers are not yet proficient in receptive vocabulary. Measuring self-regulation as a latent variable was also a means to reduce the problem of task impurity, making the construct somewhat "purer" (Miyake et al., 2000). Because latent variables capture only common variance across measures and given that the three tasks in the present study require different cognitive processes, our measure of self-regulation is less likely to include random measurement error and variance related to processes other than self-regulation (Friedman & Miyake, 2017).

In light of the dynamic interplay theory, it is also important to emphasize the potential role of context and cultural specificities that were not under study (Fischer & Bidell, 2006). The reciprocal associations between developing skills are at all times dependent on children's characteristics, context configurations, and the broader sociocultural background (Fischer & Bidell, 2006). It can be assumed by analyzing the mother's education levels and employment status, that the current sample had a medium to high sociocultural and economic status. This was not the case for previous studies analyzing reciprocal links between executive function and expressive vocabulary in Portugal (Cadima et al., 2019), based on a sample of preschoolers from socially disadvantaged backgrounds, nor the case in the United States (Bohlmann et al., 2015), based on preschoolers from mixed-income households. The fact that similar findings were reported across these three samples suggests the possibility to speculate that the mechanisms underlying the intertwined development of self-regulation and expressive vocabulary do not rely heavily on children's background. Nonetheless, studies with diverse samples concerning sociocultural backgrounds should be conducted to further explore this hypothesis.

Furthermore, mediation mechanisms not explored in the current study may play an important role in linking self-regulation related skills and expressive vocabulary. For instance, Cadima et al. (2019) discovered that the reciprocal links between executive function and expressive vocabulary were narrowed to only executive function predicting expressive vocabulary when teacher–child relationship was controlled for. Also, previous studies with preschoolers have shown that the positive association between inhibitory control and expressive vocabulary was mediated by children's engagement in the classroom tasks (Bohlmann & Downer, 2016). Warm relationships and engagement may be crucial mediation mechanisms although the current study design does not allow us to test these hypotheses. Thus, further longitudinal studies following children from the toddler to the preschool period are needed to further explore the links between self-regulation related skills and expressive vocabulary and the mediation role of teacher–child relationships and children's engagement.

Overall, our results suggest that self-regulation and expressive vocabulary skills build on each other during toddlerhood. These results are supportive of the dynamic skill theory (Fischer & Bidell, 2006). More longitudinal studies are needed to unveil the early onset of the interplay between self-regulation related skills and vocabulary skills.

Limitations and Strengths

This study has several limitations that are important to take into consideration when interpreting the findings. First, our sample may not be representative of Portuguese toddlers due to crèches selection criteria and children's sociocultural and economic context. Second, we did not collect data on children's race/ethnicity, which precludes a more complex understanding of the current sample. Third, the measure used to assess children's attention shifting is not yet validated for children under the age of 3. Nonetheless, the low percentage of missingness at assessment Waves 1 and 2 suggests that only a very low percentage of children refused to collaborate or did not understood the instructions. Also, mean levels showed developmental progression across the three waves of assessments, no floor effects were detected, and skew and kurtosis values are acceptable according to suggested clear-cut standards. Relatedly, toddlers' lack of ability on receptive language may have contributed to the extent of low performance on the measures. On that account, more research on the study and development of measures for toddlers is needed. Nevertheless, we measured self-regulation as a unitary latent construct, which reduces measurement error and enhances estimates reliability. Despite that, further studies are necessary to verify the NEPSY validity with samples of young children. Fourth, metric longitudinal invariance for self-regulation did not hold for the current sample, which may due to the low factor loadings for children's working memory, particularly at the second assessment wave. Although this measure has been validated for toddlers (Mulder et al., 2014), more studies are needed examining the adequacy of this task for toddlers. It is also important to mention that the cross-lagged panel model tested in the current study assumes that participating toddlers develop over time around the same means, not taking into consideration probable stable individual differences. Unfortunately, we were not able to test a random intercept cross-lagged panel model (Hamaker et al., 2015), because it was underidentified, and the lack of enough information to estimate all the model parameters lead to convergence problems. This limitation prevented us from partial out the between-person variance and, thus, our lagged paths cannot tell about within-person development. Still, cross-lagged panel models have been widely used and have shown to be appropriate to estimate the directionality of the relationship between two variables measured repeatedly in a longitudinal design (Bentler & Speckart, 1981; Biesanz, 2012). Sixth, we acknowledge that, given our correlational design, no strict causality links can be drawn from our findings. Processes and mechanisms not considered in the current study can have an important role in shaping the association between self-regulation and expressive vocabulary in toddlerhood and preschool, as previously discussed. Seventh, we cannot rule out the issue of task impurity, as previously discussed. Another limitation is that we did not control for children's general cognitive ability, a separate (although related) construct from self-regulation (Friedman & Miyake, 2017), that has been shown to have an important impact on the links between vocabulary and self-regulation from a very young age (Vallotton & Ayoub, 2011).

Despite these limitations, there are also several strengths to be noted. The major strength of the current study is its longitudinal design, with three time points of individual assessments. The second is the focus on toddlerhood, an understudied period of child development. At last, we used a latent factor for self-regulation. Even though this approach does not allow us to make conclusions about which self-regulation related skills contribute the most to the development of expressive vocabulary in the toddler period, it reduces measurement error.

Implications

Findings from the current study have important theoretical and practical implications. Our results can inform theoretical approaches regarding the intertwined nature of self-regulation and expressive vocabulary development during early childhood and, specifically, in toddlerhood. Designing interventions with a focus on self-regulation could also have positive effects on language development, as designing interventions with a focus on language development could also have positive effects on self-regulation at an early stage of development. Furthermore, results support self-regulation as a core and foundational skill in its own right, as is language and should be addressed as such during early childhood. In light of these findings, curricular guidelines for ECEC could benefit from approaching self-regulation and language in an embedded manner. This can be particularly informative for Portuguese educators, given the lack of specific guidelines to work with children from birth to age 3.

Conclusion

This study takes a first step in establishing the interplay between self-regulation and expressive vocabulary skills for toddlers. Our results provide support to dynamic theories of development that advocate for the intertwined nature of several skills developing in unison. The current study is an important starting point to conceive self-regulation as a core and foundational skill in its own right, alongside language.

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