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EMPIRICAL STUDY

Domain-General Cognitive Ability Predicts Bilingual Children's Receptive Vocabulary in the Majority Language

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This study investigated the influence of cognitive ability on bilingual children's vocabulary development in both their languages. Sixty-nine bilingual immigrant children participated, with data collected at three annual intervals. At Time 1, the participants were 5 or 6 years old. Receptive vocabulary was tested in the minority (Turkish, Tarifit) and majority (Dutch) languages. Cognitive measures targeted working memory, selective attention, and executive attention. Cross-lagged correlations were computed to establish the directionality of relationships. Significant partial correlations were followed by stepwise multiple regression analyses in which further control was exerted. Results showed that cognitive ability predicted receptive vocabulary 1 year later. Sequential relationships were found for the majority language only, and attention was more important than working memory. The differential patterns for the two languages set the stage for future research comparing the impact of context, timing, and type of learning on the relationship between cognition and vocabulary development.

Keywords children; bilingualism; executive functions; receptive vocabulary; longitudinal; development

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Introduction

Children's learning of academic skills is supported by domain-general cognitive abilities such as attention and working memory (Borella, Carretti, & Pelgrina, 2010; Duncan et al., 2007; Gathercole, Pickering, Knight, & Stegmann, 2004), but the impact of these abilities on language learning is unclear. For determining the impact of cognitive ability on language development, longitudinal studies are relevant because these can reveal the temporal ordering of events. Previous longitudinal research focusing on children has shown that cognitive ability predicts language (Ekerim & Selçuk, 2018; Weiland, Barata, & Yoshikawa, 2014; White, Alexander, & Greenfield, 2017) and that language predicts cognitive ability (Fuhs & Day, 2011; Kuhn, Willoughby, Vernon-Feagans, Blair, & The Family Life Project Key Investigators, 2016). Other studies have also observed a bidirectional relationship between language and cognitive ability (Bohlmann, Maier, & Palacios, 2015; Slot & Suchodoletz, 2018) or found no relationship between the two (Gooch, Thompson, Nash, Snowling, & Hulme, 2016; Lonigan, Allan, Goodrich, Farrington, & Phillips, 2017). Not only have the findings been inconsistent but conclusions regarding the impact of cognitive ability on one language have not necessarily generalized to the other language of the tested participants (Lonigan, Lerner, Goodrich, Farrington, & Allan, 2016; Tse & Altarriba, 2014). Therefore, the present study investigated relationships between bilingual immigrant children's cognitive ability and vocabulary in both the minority (Turkish, Tarifit) and majority (Dutch) languages. Data were collected three times at yearly intervals, starting when the participants were 5 or 6 years old. At all three testing times, receptive vocabulary in both languages was measured as well as working memory and attention to estimate the impact of cognitive ability on the participants' receptive vocabulary skills.

Background Literature

Cognitive Ability: Executive Functions, Attention, and Working Memory

Attention and working memory are associated with the broader domain of executive functions (Cowan, 2014; Diamond, 2013). Executive functions are higher-order cognitive functions used for goal-oriented and flexible behavior (Miller & Cohen, 2001) that develop between infancy and adolescence (Best & Miller, 2010). They include more specific functions such as updating, shifting, and inhibition (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). Updating refers to the constant monitoring and rapid addition or deletion of working memory content. Shifting is about switching attention flexibly between tasks or mental sets. Inhibition refers to the ability to override a strong prepotent or default response, that is, response inhibition. The notion of inhibition also refers to executive and selective attention, which are abilities to focus on specific goal-relevant sensory stimuli and to resist task-irrelevant distractors (Friedman & Miyake, 2004). These attentional processes prevent working memory from becoming cluttered (Diamond, 2013). They are often referred to as interference inhibition but have stronger links with working memory and the ability to keep information in an accessible state (Awh, Vogel, & Oh, 2006; Cowan, 1995; Cowan et al., 2005; Engle, Tuholski, Laughlin, & Conway, 1999; Vandierendonck, 2014) than with response inhibition (Friedman & Miyake, 2004). There are also some differences between working memory and attention. Whereas working memory is more concerned with the maintenance of information in a limited-capacity system, attention is more about the efficient encoding of relevant information, in particular in environments with many distracting inputs (Awh et al., 2006).

Attention and working memory play a significant role in learning academic skills (Borella et al., 2010; Duncan et al., 2007; Gathercole et al., 2004) and are thought to contribute to learning language beyond effects of contextual variables (Hoff, 2006; Lieven, 2010; MacLeod, Fabiano-Smith, Boegner-Pagé, & Fontolliet, 2013; Unsworth, 2016) and other cognitive functions such as verbal short-term memory (Baddeley, 2003), fluid intelligence (Paradis, 2011), statistical learning (Aslin & Newport, 2014; Lum, Conti-Ramsden, Page, & Ullman, 2012), and sensory-motor skills (Oudgenoeg-Paz, Boom, Volman, & Leseman, 2016). The assumption that domain-general cognitive ability is just one of many factors fits the view that language learning is a multicausal process, which is in line with overarching theories of cognition and development such as the dynamic systems theory (De Bot, Lowie, & Verspoor, 2007; Herdina & Jessner, 2002; Van Geert, 2008).

Relationships Between Cognitive Ability and Vocabulary

Within the myriad of factors that codetermine language development, the role of executive functions—and attention and working memory in particular—is that they support the processing of environmental stimuli (Baddeley, 2003; Cowan, 2014). Many studies have demonstrated the importance of environment and language input for children's vocabulary development (for overviews, see Hoff, 2006; Unsworth, 2016). Specific studies have delved into the question of what counts as effective input for word learning (Shneidman, Arroyo, Levine, & Goldin-Meadow, 2013). However, not only may input vary in effectiveness but children themselves also vary. Attention and working memory enable children to make sense of linguistic input as it unfolds over time, keep information in an accessible state, and refresh information (working memory), thereby focusing on what is relevant (selective attention) and ignoring what is irrelevant (executive attention). Children with better attention and more working-memory capacity may thus process the input more efficiently and, as a result, acquire more and deeper vocabulary knowledge than children with less attention and smaller working-memory capacity.

Attentional skills may moreover exert specific influence on vocabulary development by modulating fast mapping, which is the process by which children bind known words that they hear to known referents, paving the way for unknown words and referents to be paired (Carey, 2010; Carey & Bartlett, 1978). This may speed up vocabulary development because it limits learners' hypothesis space. Fast mapping may draw on executive and selective attention for respectively inhibiting and selecting lexical competitors that are activated in children's mental lexicon upon hearing a new word in the input (Yoshida, Tran, Benitez, & Kuwabara, 2011). Working memory may play a role in this process because fast-mapped words need to be retained before they are transferred to long-term memory.

Various studies have indeed found that children's performance on executive function tasks is related to their language outcomes (Kapa & Colombo, 2014; Kaushanskaya, Park, Gangopadhyay, Davidson, & Weismer, 2017; Lonigan et al., 2016; Montgomery & Evans, 2009; Verhagen & Leseman, 2016; Yoshida et al., 2011), but only a handful of studies have investigated relationships between cognitive ability and vocabulary development and used a longitudinal design. The strength of a longitudinal approach is that sequential relationships can be identified, and temporal precedence can be established. Moreover, if information on all measures is collected at all times, cross-lagged analyses can be performed. Such analyses have the potential to provide insight into the directionality of the relationship between executive function and vocabulary. Directionality is a relevant issue because not only may executive functions support children's language development but use of language may also support executive function performance because verbal mediation can enable children to regulate their thoughts and behavior (Marcovitch & Zelazo, 2009; Vygotskiĭ, 1962).

Weiland et al. (2014) found that a latent executive function variable at the beginning of preschool predicted children's receptive vocabulary at the end of preschool. A latent executive function variable is based on multiple executive function measures and does justice to the multicomponent structure of executive function while taking into account task variability and impurity (Kaushanskaya et al., 2017; Miyake et al., 2000). In Weiland et al.'s study, receptive vocabulary did not predict executive function, in contrast to other longitudinal research

(Fuhs & Day, 2011; Kuhn et al., 2016). Slot and Suchodoletz (2018), who created latent variables for executive function and language measures (receptive vocabulary, comprehension, imitation of grammatical structures), observed bidirectional relationships. The latent language variable was a stronger predictor of executive function than the other way around. Bidirectional relationships also emerged in a study by Bohlman et al. (2015), who examined sequential relationships between self-regulation and English vocabulary in monolingual and bilingual Spanish–English children. Self-regulation overlaps with executive function, requiring inhibition and working memory (Hofmann, Schmeichel, & Baddeley, 2012).

Three other longitudinal studies investigated the impact of executive function on language in a unidirectional way. One study found that a latent executive function variable predicted vocabulary (White et al., 2017). Two others focused on specific measures of inhibition. Investigating monolingual Turkish children, Ekerim and Selçuk (2018) observed that inhibition predicted vocabulary 1 year later whereas Lonigan et al. (2017) found no such effect for either of the languages in a sample of bilingual Spanish–English children. In sum, although it is theoretically expected that domain-general cognitive ability supports children's vocabulary development, empirical data to support or reject this hypothesis are still inconclusive because previous research has shown a variety of outcomes, warranting further research.

The Current Study

The specific goal of this study was to investigate if cognitive ability influences bilingual children's vocabulary outcomes. By investigating bilingual children, the impact of cognitive ability on the vocabulary development in two different languages could be examined using a within-subjects design. To our knowledge, only two studies using a longitudinal design to investigate this topic also explicitly included bilingual children (Bohlman et al., 2015; Lonigan et al., 2017). The outcomes of these studies did not agree, and only one study (Lonigan et al., 2017) investigated both languages of bilingual children.

To clarify the effect of cognitive ability on bilingual children's vocabularies in both languages, we conducted our investigation with children from immigrant families who were learning a minority and a majority language. Our study was conducted in the Netherlands and included bilinguals from two of the largest immigrant populations in the Netherlands, that is, children of Turkish and Moroccan descent. At the first measurement time, the participants were either 5 or 6 years old. At the ages tested, all participants attended kindergarten where they had received at least 1 year of substantial exposure to Dutch.

Exposure to the minority language, Turkish or Tarifit (henceforth referred to collectively as the home language), happened from birth and mostly in the home environment. The participants were tested three times at 1-year intervals. At each time of data collection, information was gathered on cognitive ability and vocabulary in Dutch and the home language. This design permitted investigation of relationships over a 2-year period and examination of the stability and directionality of relationships.

Our expectation was that cognitive abilities would predict vocabulary development (Bohlman et al., 2015; Ekerim & Selçuk, 2018; Slot & Suchodoletz, 2018; Weiland et al., 2014; White et al., 2017) because attention and working memory facilitate input processing and fast mapping, which are both relevant for learning words. Cross-lagged analyses could also demonstrate reciprocal relationships showing that verbal ability supports performance in nonverbal cognitive tasks. The sequential effect of cognitive ability was expected for Dutch and for the home language although the effect could differ in size because of the different acquisition dynamics for the two languages. Dutch is the language used at school and in the wider society and will become increasingly dominant as children go to school (Extra, Aarts, Avoird, Broeder, & Yağmur, 2001). Owing to this situation, we expected Dutch receptive vocabulary to grow steadily throughout the 2 years of data collection whereas this might not be the case for the home language. A relative decrease of home language input could make children's home language vocabulary more susceptible to the effects of cognitive ability. Effects of cognitive ability may be amplified in situations of reduced input because, in these situations, it is less likely that children who are cognitively more challenged receive enough input to counteract the effect of cognitive limitations. However, a relative decrease of home language input might also result in a lack of variation in home language vocabulary, which in turn can reduce any effects of cognitive ability on home language vocabulary development.

Other factors that may yield different patterns concern differences in the context and timing of learning Dutch and the home language, which may trigger different types of learning. Because Dutch vocabulary is learned in part at school and because Dutch is for many children their second language, learning Dutch words may be more intentional and explicit than learning home-language vocabulary. The involvement of different types of learning may have repercussions for the relationship between cognitive ability and vocabulary development. Dutch vocabulary development may draw more on higher-order cognitive processes than home-language vocabulary development, in line with studies showing that working-memory capacity is related to explicit learning

(Ellis & Sinclair, 1996) but not to implicit learning (Tagarelli, Borges-Mota, & Rebuschat, 2011).

Method

Participants

In this study, the bilingual children who participated were either second- or third-generation immigrants from Turkey or Morocco and had received regular language input in their home language from at least one parent. For the participants of Turkish descent, the home language was Turkish whereas for the participants of Moroccan descent the home language was the Berber language Tarifit. Information on input at home was collected with the Questionnaire for Parents of Bilingual Children (Tuller, 2015). All participants received regular Dutch input at school, which they attended from the age of 4 years. At Time 1, 62 participants were tested ($M_{\text{age}} = 67$ months, $SD = 7$), 23 of whom were bilingual Turkish–Dutch and 39 bilingual Tarifit–Dutch. At Time 2 and Time 3, seven additional Turkish–Dutch bilingual children were tested to achieve nearly equal numbers of Turkish–Dutch and Tarifit–Dutch participants, leading to 69 participants at Time 2 ($M_{\text{age}} = 78$ months, $SD = 8$) and Time 3 ($M_{\text{age}} = 90$ months, $SD = 8$), 30 of whom were bilingual Turkish–Dutch and 39 bilingual Tarifit–Dutch. The sample included 34 girls and 35 boys. The mean parental education was 5 ($SD = 2.28$) on a 9-point scale, which corresponds to vocational education.

Cognitive Measures

Visuospatial working memory was assessed with the backward condition of the Dot Matrix, which is a subtest from the Automated Working Memory Assessment–2 (Alloway, 2012). In this test, participants were presented with a 4×4 matrix in which sequences of dots appeared. After the last dot disappeared, participants were asked to point out the position of the dots in reverse order. In the first block, only one dot appeared, but the number of dots increased in subsequent blocks. Each block had six trials, and there was a maximum of six blocks. The Automated Working Memory Assessment–2 procedure was applied for scoring, which meant that 1 point was given for each correct trial (maximum score of 36). If the first four trials of a block were correct, participants automatically continued to a subsequent block and were awarded the maximum of 6 points. The task stopped when participants responded incorrectly to three trials within the same block. Trials were scored as incorrect if participants recalled the position of one or more dots incorrectly, if the sequence was incorrect, or if they omitted one or more dots. The test–retest reliability of the Automated Working Memory Assessment visuospatial working memory subtests ranges between .77 and .83 based on a sample ranging in age between 4.5 and 11.5 years (Alloway, Gathercole, & Pickering, 2006).

Selective attention was tested with the visual Sky Search subtest of the Test of Everyday Attention for Children (Manly, Robertson, Anderson, & Nimmo-Smith, 1999). This subtest measures selective attention because test takers have to focus on specific targets in an environment with many distractors. In the first part of the test, participants had to circle identical pairs of spaceships on an A3 sheet of paper. Twenty identical pairs were the targets, and 108 nonidentical pairs were the distractors. Participants were instructed to circle the targets as fast as possible while ignoring the distractors. They were familiarized with the procedure during a practice phase. To control for drawing speed and participants' motor abilities, a second A3 sheet of paper was given to the participants after they had completed the first part of the task. On this motor-control sheet, only the 20 identical spaceships were displayed, and participants were again asked to circle them as fast as possible. Participants' selective attention score was calculated by subtracting the mean time per target of the motor-control sheet from the mean time per target of the sheet on which both targets and distractors were displayed. The test–retest reliability of the visual Sky Search subtest is .90 and .75 when age is partialed out (Manly et al., 2001).

Executive attention was measured with a flanker task from Engel de Abreu, Cruz-Santos, Tourinho, Martin, and Bialystok (2012), who modified the child's version of the Attention Network Task developed by Rueda et al. (2004). The flanker task was administered on a laptop using the experimental software E-Prime 2.0 (Schneider, Eschman, & Zuccolotto, 2002). A horizontal row of five equally spaced yellow fish was presented to the participants. The participants were asked to indicate the direction of the central fish by pressing the corresponding left or right response button as fast as possible. On congruent trials (50%), the flanking fish were pointing in the same direction as the central target fish; on incongruent trials (50%), the flanking distractors pointed in the opposite direction. Each trial started with a fixation cross in the middle of the screen (1,000 milliseconds), followed by the presentation of the five fish. A response had to be made within 5,000 milliseconds or it was considered incorrect. All participants completed two blocks of 20 trials in which presentation of congruent and incongruent trials was randomized. Eight practice trials preceded the test phase. Accuracy and reaction times (RTs) were documented, but we focused on RTs because mean accuracy scores were high, in particular at Times 2 and 3 (Time 1 = 83%, Time 2 = 92.5%, Time 3 = 96.5%). Following the procedures of Engel de Abreu et al. (2012), we calculated mean RTs excluding incorrect responses, RTs below 200 milliseconds, and RTs above three standard deviations of participants' individual means. The test–retest reliability of the flanker task used in the present study was not reported in Engel de Abreu et al. (2012), hence it is unknown.

Fluid intelligence was measured with the short version of the Wechsler Nonverbal Scale of Ability–Nederlandstalige bewerking (Wechsler & Naglieri, 2008), comprising the Matrices and Recognition subtests. Standardized scores were calculated with a mean of 100 and a standard deviation of 15. For children ages 5 to 8 years, which is the age range investigated in the current study, the test–retest reliabilities of the Matrices and Recognition subtests range between .81 and .90. Verbal short-term memory was measured with a digit span forward test, based on the digit recall subtest of the Automated Working Memory Assessment. Participants were asked to repeat a sequence of digits in the exact same order as the sequence was presented to them. Two practice items familiarized participants with the procedure. The task started with a block of six trials in which one digit was presented and continued with digit sequences of increasing length, up to a maximum of seven digits. Testing stopped after participants incorrectly repeated three items in one block. This entailed a wrong ordering of the sequence, an omission of one or more digits, or repetition of one or more incorrect digits. Participants received one point for each correctly repeated sequence and were awarded six points if the first four trials within a block were correct. Scores could thus range from 0 to 42. The test–retest reliability of the Automated Working Memory Assessment digit recall subtest is .84 (Alloway et al., 2006).

Language Measures

Dutch proficiency was measured with the Peabody Picture Vocabulary Task-III-NL (PPVT; Dunn, Dunn, & Schlichting, 2005). The PPVT is a standardized receptive vocabulary test designed for a wide age range (2 years 3 months–90 years). Participants hear a target word and have to pick the correct referent out of four pictures. The task is divided into 17 sets that increase in difficulty, with 12 target words in each set. Scores were calculated according to the official guidelines of the PPVT. For each participant, the starting set was based on his/her age, and the final set was the first set in which that participant picked the incorrect referent picture nine or more times. Raw scores were calculated and used in the analyses by subtracting the total number of errors made between the basal and ceiling item sets from the ceiling item. The test–retest reliability of the PPVT, based on a sample of adults, is .94 (Dunn et al., 2005).

For the purpose of the present study, comparable tasks for Turkish and Tarifit were developed by translating the PPVT, for which permission was obtained from the publisher. Translated versions of standardized tests are suboptimal, but we chose this method because no comparable measures were available in Dutch, Turkish, and Tarifit for the age range (i.e., 5–8 years) and population (i.e., second- or third-generation immigrants) in our study. Items that fluent Turkish–Dutch and Tarifit–Dutch speakers considered much easier or more difficult than the target words in the Dutch version were excluded. The same was done for Turkish and Tarifit translations that were cognates of the Dutch target words. This resulted in the deletion of four items per set, yielding a total of eight items per set for the first eight sets. For the remaining, higher sets, no translations were made due to the increasing number of cognates and the difficulty of finding proper translation equivalents, in particular for Tarifit. In total, the tests contained 64 items.

Internal consistency and reliability of the Turkish and Tarifit versions, estimated based on our sample, was good: Cronbach's α ranged between .76 and .90 (Turkish Time 1 = .90, Turkish Time 2 = .84, Turkish Time 3 = .86, Tarifit Time 1 = .76, Tarifit Time 2 = .82, Tarifit Time 3 = .81). To validate the test, correlations between participants' raw vocabulary scores and exposure to the home language at home were calculated (Scheele, Leseman, & Mayo, 2010). The Questionnaire for Parents of Bilingual Children (Tuller, 2015) provided information about home-language richness and home-language use. Home-language richness, which was an aggregate score based on how frequently the participants were engaged in specific activities such as book reading, watching movies, or oral storytelling in the home language, correlated significantly with home-language vocabulary at Time 1, $r(54) = .60$, $p < .001$, Time 2, $r(62) = .69$, $p < .001$, and Time 3, $r(62) = .67$, $p < .001$. The same held for home-language use, which was an aggregate score of how frequently the participants were engaged in interactions in the home language with their parents and siblings, at Time 1, $r(53) = .66$, $p < .001$, Time 2, $r(61) = .67$, $p < .001$, and Time 3, $r(61) = .68$, $p < .001$.

Procedure

Our study was part of a large-scale project that aimed to investigate the cognitive and linguistic development of monolingual and bilingual children. This project was approved by the Standing Ethical Assessment Committee of the Faculty of Social and Behavioral Sciences at Utrecht University. Informed consent forms were signed by parents of participants. The bilingual participants were individually tested by a native speaker of Dutch and by a native speaker of

Turkish or Tarifit in two separate sessions that each lasted approximately 1 hour to reduce test time and keep participants engaged. Testing took place in a quiet room in a school. Similar procedures were used for each testing session. As there was one full year between each data collection session, it is unlikely that any improvements were due to test repetition. The parental questionnaire was administered at Time 1 during a telephone interview in the language that the parents preferred.

Data Analysis

In the preliminary analyses, distributions of the cognitive measures (i.e., working memory tested with the Dot Matrix test, selective attention tested with the Sky Search test, and executive attention tested with the flanker task) and the two language measures (i.e., Dutch receptive vocabulary, home language receptive vocabulary) were checked. Developmental patterns were analyzed using a repeated-measures analysis of variance (ANOVA) with time (Time 1, Time 2, Time 3) as the within-subjects variable. Bonferroni post hoc tests were used for comparisons across testing times if the effect of time was significant. To estimate effect sizes, Cohen's d was calculated with a correction for within-subjects effects (Cohen, 1998; Morris & DeShon, 2002). As a rule of thumb, $d = 0.2$ refers to a small effect, $d = 0.5$ to a medium effect, and $d = 0.8$ to a large effect (Cohen, 1998). However, Plonsky and Oswald (2014) proposed field-specific recommendations for interpreting effect sizes in applied linguistics, where $d = 0.4$ refers to a small effect, $d = 0.7$ to a medium effect, and $d = 1.0$ to a large effect

Correlations between the three cognitive measures were run and principal component analysis was used to test if the three measures could be reduced to one factor that could be used in further analyses. The rationale for this reduction was twofold. First, it allowed us to reduce the number of correlational analyses from 54 (three testing sessions, three tests, both directions) to 18. Second, as explained earlier, working memory and attention are closely related (Awh et al., 2006; Cowan, 1995; Cowan et al., 2005; Engle et al., 1999) and principal component analysis may tap into a shared underlying construct, which is better represented by an index based on multiple tasks than separate tasks (Kaushanskaya et al., 2017; Miyake et al., 2000). As the sample size was too small for structural equation modeling and the extraction of a latent variable, principal component analysis was used. In the case of support for a one-component solution, the saved factor scores would be used to examine the relationship between cognitive ability and vocabulary.

To investigate if cognitive ability predicted vocabulary, three analyses were performed. First, cross-lagged correlational analyses were run, that is, correlations between cognition Time 1 and vocabulary Time 2, cognition Time 2 and vocabulary Time 3, vocabulary Time 1 and cognition time 2, vocabulary Time 2 and cognition Time 3, to identify significant associations and establish the direction of these relationships. Second, cross-lagged partial correlations were run to focus on sequential relationships (e.g., correlations between cognition Time 1 and vocabulary Time 2 controlling vocabulary Time 1, etc.). Third, significant partial correlations were followed by stepwise multiple regression analyses to test if the sequential relationships were robust and direct when more control variables were added. Specifically, what we wanted to know was whether the predictor of interest (e.g., cognition Time 1) still explained unique variance in the outcome variable (e.g., vocabulary Time 2) if fluid intelligence, verbal short-term memory, and parental education were added to the regression models, in addition to the autoregressive effect.

The choice of predictors in the third step was determined a priori based on findings in previous literature showing that fluid intelligence and verbal short-term memory impact vocabulary development (Baddeley, 2003; Paradis, 2011) and are related to executive function (Friedman et al., 2006; Lukács, Ladányi, Fazekas, & Kemény, 2016). For similar reasons, the child-external factor, parental education, was added (Ardilla, Rosselli, Matute, & Guajardo, 2010; Hoff, 2006). To avoid overfitting the models, the number of predictors was limited to five, in line with the rule of thumb that, to allow good estimates, a minimum of 10 to 15 observations per predictor variable is required (Babyak, 2004). Using stepwise regression, the four control measures were entered in Step 1 (Model 1), and the predictor of interest—cognition Time 1, cognition Time 2, vocabulary Time 1, vocabulary Time 2—in Step 2 (Model 2) to determine if the predictor explained variation in the outcome variable—vocabulary Time 2, vocabulary Time 3, cognition Time 2, cognition Time 3—over and above the variation explained by the control variables. If this was the case, follow-up analyses were performed in which we repeated the stepwise regressions for the three cognitive tasks (working memory, selective attention, executive attention) separately to identify whether or not a more specific cognitive function carried the effect and did so independently of any of the other cognitive functions.

Results

Preliminary Analyses: Cognitive Ability

Table 1 shows the results for working memory (Dot Matrix test), selective attention (Sky Search test), and executive attention (flanker task) at the three

Table 1 Means (standard deviations) for working memory and attention scores at the three testing times

Time	Dot Matrix: accuracy	Sky Search: selective attention	Flanker congruent: RT (ms)	Flanker incongruent: RT (ms)
Time 1	10.81 (4.00)	12.80 (8.32)	1,584 (475)	1,794 (587)
Time 2	13.96 (5.42)	7.50 (3.75)	1,300 (463)	1,509 (541)
Time 3	16.60 (5.49)	5.28 (2.08)	1,003 (347)	1,147 (440)

measurement times. Preliminary analyses showed that the Dot Matrix outcomes deviated from a normal distribution at Times 1 and 2. Because transformations did not improve the distributions, and skew and kurtosis were within the ± 1 range, indicating mild violations, we decided to use parametric tests. Both the Sky Search test and flanker task outcomes deviated from normality but log transformations improved the distributions considerably. In addition to the RTs in the congruent and incongruent condition of the flanker task, we calculated the flanker effect by subtracting the RTs in the congruent condition from RTs in the incongruent condition. The flanker effect is a measure of resistance to interference. The distribution of the flanker effect scores deviated strongly from normality, and this could not be remedied by transformations. Therefore, RTs in the congruent and incongruent condition were used in the analyses, similar to what Engel de Abreu et al. (2012) did. Specifically, RTs in the incongruent condition were relevant because, in this condition, the participants had to ignore distractors. Using Spearman's rho, we found that RTs in the incongruent condition correlated significantly with the flanker effect at Time 1, $r_s(62) = .48, p < .001$, Time 2, $r_s(69) = .52, p < .001$, and Time 3, $r_s(68) = .53$, $p < .001$, in contrast to the RTs in the congruent condition at Time 1, $r_s(62) = -.11, p = .39$, Time 2, $r_s(69) = .07, p = .59$, and Time 3, $r_s(68) = .19$, $p = .13$. Analyses were performed for the whole sample and checked for the Turkish and Moroccan groups separately; differential outcomes are reported. The same procedure was followed for the language measures.

A repeated-measures ANOVA with time (Time 1, Time 2, Time 3) as the within-subjects variable indicated that nonverbal working memory of the participants improved over time, $F(2, 114) = 47.72$, $p < .001$, $\eta_p^2 = .46$. Bonferroni-corrected pairwise comparisons showed improvement from Time 1 to Time 2 ($p < .001$, $d = 0.76$, 95% confidence interval [CI] [–4.83, –2.03]) and from Time 2 to Time 3 ($p = .001$, $d = 0.53$, 95% CI [–4.42, –0.99]). A repeated-measures ANOVA with time (Time 1, Time 2, Time 3) as the within-subjects variable indicated growth on the selective attention test, $F(2, 118) = 91.14, p < .001, \eta_p^2 = .61$. Bonferroni-corrected pairwise comparisons showed improvement from Time 1 to Time 2 ($p < .001$, $d = -0.90$, 95% CI [0.34, 0.67]) and from Time 2 to Time 3 ($p < .001$, $d = -0.72$, 95% CI [0.20, 0.50]). A repeated-measures ANOVA with time (Time 1, Time 2, Time 3) as within-subjects variable revealed main effects of time, $F(2, 120) = 84.15$, $p < .001$, $\eta_p^2 = .58$, and of condition, $F(1, 60) = 4.91$, $p = .031$, $\eta_p^2 = .08$, for the flanker task, showing that the participants were faster at older ages and that RTs were longer for the incongruent than the congruent condition, as expected. To unpack the effect of time in the incongruent condition of the flanker task, Bonferroni-corrected pairwise comparisons were performed that showed improvement from Time 1 to Time 2 ($p = .005$, $d = -0.42$, 95% CI [0.05, 0.31]) and from Time 2 to Time 3 ($p < .001$, $d = -0.89$, 95% CI [0.16, 0.37]).

At all three times, the Pearson correlations between the cognitive measures reached significance ($p < .05$), as shown in Appendix S1 in the Supporting Information online. We first examined the possibility of reducing the three cognitive measures to one factor score using a principal component analysis for the outcomes of the Dot Matrix test, Sky Search test, and RTs on the incongruent condition of the flanker task. The principal component analysis indicated support for a one-factor solution, which explained, respectively, 63% of the variance at Time 1, 65% at Time 2, and 56% at Time 3. Correlations between the measures, anti-image correlations, and measures of sampling adequacy indicated that the factorability was good. Correlations between the three measures were sizeable at Time 1 and Time 2 (>.3), and a bit weaker at Time 3. All anti-image correlations were above .5. The Kaiser-Meyer-Olkin measure of sampling adequacy was .67 at Time 1, .68 at Time 2, and .61 at Time 3, and Bartlett's test of sphericity was significant at all three times. In subsequent correlational analyses of the relationship between cognition and language, the saved factor scores were used. A lower score indicated better performance.

Preliminary Analyses: Vocabulary

The results for Dutch and home-language vocabulary at the three times are summarized in Table 2. A repeated-measures ANOVA indicated that the participants improved over time on Dutch vocabulary, $F(2, 114) = 134.67, p < .001$, $\eta_p^2 = .70$. Bonferroni-corrected pairwise comparisons showed improvement from Time 1 to Time 2 ($p < .001$, $d = 0.98$, 95% CI [–12.80, –6.72]) and from Time 2 to Time 3 ($p < .001$, $d = 0.99$, 95% CI [–13.20, –7.80]). For

Table 2 Means (standard deviations) for raw vocabulary scores in Dutch and home language at the three testing times

Time	Dutch	Home language
Time 1	73.42 (11.00)	34.41 (9.97)
Time 2	83.04 (12.21)	38.37 (10.76)
Time 3	91.97 (11.49)	39.85 (12.14)

Table 3 Product-moment and partial correlation coefficients between cognitive ability and Dutch vocabulary at the three testing times

	Cognition Time 1		Cognition Time 2		Cognition Time 3	
Dutch vocabulary	*r*	partial *r*	*r*	partial *r*	*r*	partial *r*
Time 1	–.22	–	–.29*	–.16	–.34**	–.27†
Time 2	–.33*	–.31*	–.30*	–	–.31**	–.14
Time 3	–.32*	–.27†	–.41***	–.30*	–.34**	–

Note. Light grey cells are sequential relations between cognition and vocabulary; dark grey cells represent sequential relations between vocabulary and cognition. †$p = .05$, *$p < .05$, **$p < .01$, ***$p < .001$.

development of vocabulary in the home language, a second repeated-measures ANOVA was performed, which indicated improvement of home-language vocabulary, $F(2, 108) = 5.71, p = .004, \eta_p{}^2 = .10$. Bonferroni-corrected pairwise comparisons showed improvement from Time 1 to Time 2 ($p = .03$, $d = 0.59$, 95% CI [–4.65, –0.18]) but not from Time 2 to Time 3 ($p = .96$, $d = 0.20$, 95% CI [–3.65, 1.54]). Separate analyses for the Turkish and Moroccan groups demonstrated different patterns, revealing improvement in the Turkish group, $F(2, 38) = 50.86$, $p < .001$, $\eta_p{}^2 = .73$, but not in the Moroccan group, $F(2, 68) = 0.24$, $p = .79$.

Relationships Between Cognitive Ability and Vocabulary

Dutch

Table 3 summarizes the correlations between the saved factor scores for the cognitive tests and Dutch vocabulary at the three times. Sequential relationships between cognitive ability and Dutch vocabulary are marked with light grey cells whereas sequential relationships in the reverse direction are in the dark grey cells. For reasons of power and because no differences between the Turkish and Moroccan groups emerged for the cognitive tests and for Dutch vocabulary, data from the two groups were combined. Significant correlations emerged for the sequential relationship between cognitive ability and Dutch vocabulary and, conversely, between Dutch vocabulary and cognitive ability, in the expected direction. The sign is negative because a lower cognitive ability score reflects better performance whereas a lower vocabulary score reflects poorer performance. A significant concurrent relationship between cognitive ability and Dutch vocabulary gradually increased in strength between Time 1 and Time 3 and was significant at Time 2 and Time 3, but not at Time 1. Partial correlations between cognitive ability Time 1 and Dutch vocabulary Time 2, controlling for Dutch vocabulary Time 1, and between cognitive ability Time 2 and Dutch vocabulary Time 3, controlling for Dutch vocabulary Time 2, were significant, confirming that better cognitive abilities preceded better vocabulary scores. Partial correlations in the other direction did not reach significance. The partial correlations between Dutch vocabulary Time 1 and cognition Time 3, controlling for cognition Time 1, and between cognition Time 1 and Dutch vocabulary Time 3, controlling for Dutch vocabulary Time 1, were both marginally significant ($p = .05$).

Two sets of multiple regression analyses were performed to determine if the significant partial correlations reflected a robust sequential relationship between cognitive ability and Dutch vocabulary by exerting further control. The first set of analyses looked at Time 1 predictors of Dutch vocabulary Time 2. The second set of analyses examined Time 2 predictors of Dutch vocabulary Time 3. The zero-order correlations related to the two sets of analyses are provided in Appendix S2 in the Supporting Information online. The first set of analyses showed that Model 1, which included fluid intelligence, verbal short-term memory Time 1, parental education, and Dutch vocabulary Time 1, was significant. Of the four control variables, only Dutch vocabulary Time 1 was significant ($p < .001$). In Model 2, cognition Time 1 was added to the model, yielding a significant R^2 change ($p = .018$, adjusted R^2 Model 1 = .36, adjusted R^2 Model 2 = .43). The results are displayed in Table 4. Follow-up analyses in which we repeated the statistical procedure for the three cognitive tasks separately demonstrated a predictive effect for the selective attention task, revealed by a significant R^2 change ($p = .022$, adjusted R^2 Model 1 = .39, adjusted R^2 Model 2 = .44), as indicated by the results in Table 5. No effects emerged for working memory and executive attention, as summarized in Appendix S3 in the Supporting Information online. To establish if the effect of selective attention was independent of working memory and executive attention, multiple regression analyses were run with Dutch vocabulary Time 1, working memory, and executive attention scores entered in Model 1 and selective attention entered

Table 4 Cognition Time 1 predicting Dutch vocabulary Time 2, controlling for fluid intelligence, verbal short-term memory, parental education, and Dutch vocabulary Time 1

Model	*b*	*SE*	β	*t*	*p*
1 Constant	22.662	12.517		1.810	.077
Fluid intelligence	0.151	0.095	.195	1.579	.122
Verbal short-term memory Time 1	0.208	0.393	.065	0.529	.599
Parental education	–0.232	0.562	–.049	–0.412	.682
Dutch vocabulary Time 1	0.602	0.122	.592	4.950	<.001
2 Constant	41.408	14.064		2.944	.005
Fluid intelligence	0.085	0.094	.110	0.907	.369
Verbal short-term memory Time 1	–0.258	0.416	–.081	–0.620	.539
Parental education	–0.392	0.536	–.084	–0.732	.468
Dutch vocabulary Time 1	0.556	0.117	.547	4.775	<.001
Cognition Time 1	–3.462	1.403	–.343	–2.468	.018

Table 5 Selective attention Time 1 predicting Dutch vocabulary Time 2, controlling for fluid intelligence, verbal short-term memory, parental education, and Dutch vocabulary Time 1

Model	*b*	*SE*	β	*t*	*p*
2 Constant	42.232	14.955		2.842	.007
Fluid intelligence	0.106	0.090	.133	1.183	.243
Verbal short-term memory Time 1	0.127	0.365	.040	0.347	.730
Parental education	–0.534	0.542	–.112	–0.985	.330
Dutch vocabulary Time 1	0.606	0.114	.587	5.307	<.001
Sky Search Time 1	–5.450	2.297	–.281	–2.372	.022

in Model 2. This analysis confirmed that the effect of selective attention was independent of the other cognitive functions (Table 6).

The second set of analyses showed that Model 1, which included fluid intelligence, verbal short-term memory Time 2, parental education, and Dutch vocabulary Time 2, was significant. Of the control variables, only Dutch vocabulary Time 2 was significant ($p < .001$). In Model 2, cognition Time 2 was added, yielding a significant R^2 change ($p = .045$, adjusted R^2 Model 1 = .49, adjusted R^2 Model 2 = .52). The results are shown in Table 7. Separate regression models for the three cognitive tasks showed that a predictive effect emerged for the executive attention task (R^2 change $p = .021$, adjusted R^2 Model 1 = .49, adjusted R^2 Model 2 = .53) and was independent of working memory

Table 6 Selective attention Time 1 predicting Dutch vocabulary Time 2, controlling for working memory Time 1, executive attention Time 1, and Dutch vocabulary Time 1

Model	*b*	*SE*	β	*t*	*p*
1 Constant	72.558	28.110		2.581	.013
Dot Matrix Time 1	0.097	0.333	.036	0.292	.772
Flanker incongruent Time 1	–4.610	3.545	–.154	–1.300	.199
Dutch vocabulary Time 1	0.602	0.110	.606	5.471	<.001
2 Constant	64.720	27.160		2.383	.021
Dot Matrix Time 1	–0.047	0.325	–.017	–0.145	.885
Flanker incongruent Time 1	–1.151	3.700	–.038	–0.311	.757
Dutch vocabulary Time 1	0.566	0.107	.569	5.304	<.001
Sky Search Time 1	–5.657	2.385	–.286	–2.372	.021

Table 7 Cognition Time 2 predicting Dutch vocabulary Time 3, controlling for fluid intelligence, verbal short-term memory, parental education, and Dutch vocabulary Time 2

Model	*b*	*SE*	β	*t*	*p*
1 Constant	35.527	10.157		3.498	.001
Fluid intelligence	0.038	0.078	.049	0.487	.628
Verbal short-term memory Time 2	–0.008	0.325	–.002	–0.024	.981
Parental education	0.475	0.494	.095	0.962	.341
Dutch vocabulary Time 2	0.619	0.096	.683	6.435	<.001
2 Constant	47.926	11.558		4.147	<.001
Fluid intelligence	–0.016	0.080	–.020	–0.196	.845
Verbal short-term memory Time 2	–0.255	0.338	–.080	–0.756	.453
Parental education	0.339	0.484	.068	0.700	.487
Dutch vocabulary Time 2	0.603	0.094	.666	6.440	<.001
Cognition Time 2	–2.413	1.175	–.226	–2.054	.045

and selective attention (see Tables 8 and 9). No predictive effects emerged for working memory and selective attention, as summarized in Appendix S4 in the Supporting Information online.

Home Language

Concurrent relationships were not significant. The only sequential correlation that reached significance was between home-language vocabulary Time 2 and cognition Time 3, but this relationship was rendered nonsignificant when cognition Time 2 was controlled for, as indicated in Table 10. For this reason, no multiple regression analyses were performed.

Table 8 Executive attention Time 2 predicting Dutch vocabulary Time 3, controlling for fluid intelligence, verbal short-term memory, parental education, and Dutch vocabulary Time 2

Model	*b*	*SE*	β	*t*	*p*
2 Constant	92.332	26.055		3.543	.001
Fluid intelligence	0.005	0.075	.007	0.069	.945
Verbal short-term memory Time 2	–0.127	0.314	–.039	–0.403	.689
Parental education	0.408	0.465	.084	0.878	.384
Dutch vocabulary Time 2	0.627	0.092	.688	6.845	<.001
Flanker incongruent Time 2	–7.079	2.969	–.230	–2.384	.021

Table 9 Executive attention Time 2 predicting Dutch vocabulary Time 3, controlling for working memory, selective attention, and Dutch vocabulary Time 2

Model	*b*	*SE*	β	*t*	*p*
1 Constant	43.769	10.321		4.241	<.001
Dot Matrix Time 2	0.245	0.199	.122	1.231	.223
Sky Search Time 2	–1.748	2.462	–.073	–0.710	.480
Dutch vocabulary Time 2	0.586	0.087	.646	6.721	<.001
2 Constant	93.822	23.713		3.975	<.001
Dot Matrix Time 2	0.047	0.210	.024	0.225	.823
Sky Search Time 2	0.649	2.591	.027	0.251	.803
Dutch vocabulary Time 2	0.633	0.087	.697	7.309	<.001
Flanker incongruent Time 2	–7.677	3.300	–.252	–2.326	.023

Discussion

The key objective of this study was to answer the question, Do higher-order domain-general cognitive abilities, specifically attention and working memory, influence the vocabulary development of bilingual immigrant children in the majority and minority (home) languages? In the context of the Netherlands, where the study was conducted, Dutch is the majority language. The participating children were raised in families of Turkish or Moroccan descent and had, respectively, Turkish or Tarifit as their home language. The cognitive tests measured working memory, selective attention, and executive attention.

A principal component analysis provided support for one component representing cognitive ability and confirmed links between working memory and attention (Awh et al., 2006; Cowan, 1995; Cowan et al., 2005; Engle et al., 1999; Vandierendonck, 2014). The saved factor scores were used in subsequent correlational analyses, which showed that cognitive outcomes predicted

Table 10 Product-moment correlation and partial correlation coefficients between cognitive ability and home language vocabulary at the three testing times

Home language vocabulary	Cognition Time 1		Cognition Time 2		Cognition Time 3	
	r	partial *r*	*r*	partial *r*	*r*	partial *r*
Time 1	–.12	–	–.17	–.07	–.20	–.15
Time 2	–.15	–.16	–.24	–	–.30*	–.21
Time 3	–.11	–.09	–.10	.11	–.15	–

Note. Light grey cells are sequential relationships between cognition and language; dark grey cells are sequential relationships between language and cognition. $^{*}p < .05$.

Dutch receptive vocabulary both at Time 1, when the participants were 5 or 6 years old, and Time 2, when the participants were 6 or 7 years old. Stepwise multiple regression analyses in which autoregressive effects, fluid intelligence, verbal short-term memory, and parental education were controlled for, confirmed that cognitive ability at Time 1 influenced Dutch receptive vocabulary at Time 2. Follow-up analyses revealed that scores on the Sky Search test, which measures selective attention, were responsible for this effect. The effect of selective attention existed independent of working memory and executive attention. A year later, the sequential effect of cognitive ability also reached significance, that is, cognitive ability Time 2 predicted Dutch receptive vocabulary Time 3. This time, the effect was carried by the flanker task, which measures executive attention. Again, this effect existed independently of the other cognitive measures. Neither fluid intelligence, verbal short-term memory, nor parental education were significant predictors in any of the multiple regression analyses.

The observation that our bilingual early-school-age participants with more cognitive resources developed larger vocabularies supports previous results (Bohlman et al., 2015; Ekerim & Selçuk, 2018; Slot & Suchodoletz, 2018; Weiland et al., 2014; White et al., 2017) and confirms the relevance of higher-order cognition for language learning (Cowan, 2014; Diamond, 2013). Partial correlations suggested unidirectionality. In regard to directionality, our findings are very similar to those of Weiland et al. (2014), who investigated English receptive vocabulary in a sample of children who were from diverse backgrounds (about half of them being exposed to a non-English language at home) and were somewhat younger than the children in our study. Our findings partially converge with studies that observed bidirectional relationships (Bohlman et al., 2015; Slot & Sudocholetz, 2018), suggesting verbal mediation

(Vygotskiĭ, 1962). However, Slot and Sudocholetz did not investigate vocabulary but extracted a latent language variable based on both vocabulary and grammar measures. Two other studies that reported that language predicts cognitive ability focused on expressive vocabulary (Bohlman et al., 2015; Fuhs & Day, 2011). A common verbal mediation strategy is self-talk. For self-talk, expressive vocabulary may be more relevant than receptive vocabulary (Weiland et al., 2014).

One important aspect that distinguishes our study from research by Bohlman et al. (2015), who also investigated bilingual immigrant children, is that our study examined vocabulary in both languages. A recent study by Lonigan et al. (2017) with Spanish–English bilingual children did consider both languages. These researchers found that inhibition did not predict majority (English) or minority (Spanish) language vocabulary. Our findings revealed that cognitive ability did not correlate with vocabulary in the minority language (Turkish, Tarifit) but did predict majority language (Dutch) vocabulary. This latter observation converges with the study by Bohlman et al., in which vocabulary in the majority language (English) of bilingual children was predicted by self-regulation.

Possible explanations for the discrepancy in the findings between this study and the study by Lonigan et al. (2017) may be related to the measures that they used. Cognitive ability was tested using the head-toes-knees-shoulders task. In this task, participants had to do the opposite of a command spoken by the examiner, requiring them to suppress a default response. To assess vocabulary, a definitional vocabulary test was used in which the participants had to mention the function or relevant context for an item presented to them. The use of one response inhibition test may have limited any findings because children’s behavior on executive function tasks is variable, and single tests are seldom pure measures of assumed underlying constructs (Kaushanskaya et al., 2017; Miyake et al., 2000). In addition, a definitional vocabulary test might be relatively sensitive to domain-specific knowledge and less to domain-general cognitive ability, unlike the simple matching tasks used in our study to measure receptive vocabulary and by Bohlman et al. (2015) to measure expressive vocabulary.

Dutch receptive vocabulary grew steadily throughout the 2 years of data collection in contrast to home-language vocabulary. Limited growth in the home language may have depressed any effects of cognitive ability in our study. The different developmental trajectories for vocabulary development in Dutch and the home language reflected a growing predominance of Dutch, which is the dominant language in the Netherlands. Separate analyses suggested that the participants of Moroccan descent, who were exposed to Tarifit at home, showed stagnation in the home-language vocabulary whereas the Turkish-speaking participants improved in Turkish. This difference converges with findings from previous research demonstrating relatively more use of the home language and less of use of Dutch in Turkish families than in Moroccan families (Scheele et al., 2010). Scheele et al. observed that this difference influenced children's Dutch vocabulary whereas in our study differences emerged for the home language. The participants in our study were older than the 2–3 year-olds studied by Scheele et al. Frequent Dutch input at school may have equalized any effects of Dutch at home in our study. In addition to growth and proficiency, a factor that deserves further attention is the degree to which contexts and types of learning explain the differential findings for the majority and minority language. Immigrant children learn the majority language in part at school and often as a second language. As a consequence, majority-language vocabulary may be learned in a more intentional, explicit way than home-language vocabulary; this may have crucial consequences for the neurocognitive mechanisms involved (Ellis, 2015; Ellis & Sinclair, 1996; Hulstijn, 2003; Tagarelli et al., 2011; Yang & Li, 2012).

The study also yielded outcomes that were not foreseen. We had expected that attention and working memory would predict vocabulary development because efficient encoding and retention are both relevant for input processing (Cowan, 2014; Diamond, 2013) and fast mapping (Carey, 2010; Carey & Bartlett, 1978; Yoshida et al., 2011). However, sequential effects emerged for the attention measures only, suggesting that efficient encoding of sensory inputs—and suppressing distractors—is more important for receptive vocabulary development than retaining information in an accessible state. Selective attention emerged as a significant predictor between Times 1 and 2, while executive attention was significant between Times 2 and 3. Because of task variability and overlap of selective and executive attention (Friedman & Miyake, 2004), we are hesitant to interpret this contrast developmentally. The correlational analyses showed a significant concurrent relationship between cognitive ability and Dutch vocabulary at Times 2 and 3 but not at Time 1. The strength of this relationship increased over time, suggesting that age, or relatedly number of years of schooling, plays a role. The concurrent relationship might not only reflect an association between cognitive ability and vocabulary size but also between cognitive ability and performing a (picture-matching) task. Fluid intelligence, verbal short-term memory, and parental education did not predict participants' vocabulary in our study. The inclusion of autoregressive effects in the regression models may have rendered any of these control variables nonsignificant.

In addition, the participants' age may have played a role because both verbal short-term memory (Baddeley, 2003) and parental education (Letts, Edwards, Sinka, Schaefer, & Gibbons, 2013) are stronger predictors of vocabulary and language development at younger (preschool) ages.

Conclusion

This study demonstrated that cognitive ability impacts on children's vocabulary development. It must be emphasized, however, that any conclusions about causal connections that are based on cross-lagged analyses are tentative (Kearney, 2017). In contrast to some other studies (Bohlman et al., 2015; Fuhs & Day, 2011; Kuhn et al., 2016; Slot & Sudocholetz, 2018), we did not find that verbal ability predicted cognitive outcomes. The sample size as well as the number of measures in the current study were limited. Research with a larger sample is recommended as well as with cognitive tasks where verbal mediation is likely to occur. Unidirectionality in our study may moreover be related to the receptive modality. Although receptive and expressive vocabulary may measure the same construct (Lonigan & Milburn, 2017), expressive vocabulary is probably more relevant for verbal mediation than is receptive vocabulary (Weiland et al., 2014). Avenues for future research include looking beyond vocabulary into other aspects of language development that may be supported by cognition in addition to comparing different vocabulary measures. Experimental learning studies that manipulate children's ability to encode rather than to retain information may shed light on the relationship between working memory and attention and word learning. Finally, the results of this study set the stage for future research with bilingual children that investigates whether and how the dynamics of acquisition—specifically, in contexts, timing, and types of learning—impact the relationship between cognitive ability and vocabulary development.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1. Correlations Between Cognitive Measures.
Appendix S2. Zero-Order Correlations.
Appendix S3. Relationship Between Working Memory, Executive Attention, and Dutch Vocabulary (Time 2).
Appendix S4. Relationship Between Working Memory, Selective Attention, and Dutch Vocabulary (Time 3).

Appendix: Accessible Summary (also publicly available at https://oasis-database.org)

Bilingual Children With Better Attention Know More Words

What This Research Was About and Why It Is Important

The number of words children know is a key predictor of their later academic success. It is therefore important to understand what drives children's vocabulary development. The vocabulary development of immigrant children is of particular relevance as in many countries immigrant children have less academic success than their non-immigrant peers. In this study, the researchers investigated whether and how the cognitive ability of bilingual immigrant children—in terms of their attention and memory abilities—is relevant for their vocabulary development in the majority and minority (home) languages. The children's development was followed for two years. The researchers found that children with stronger cognitive abilities knew more words in the majority language than children with weaker cognitive abilities. Cognitive ability was irrelevant for vocabulary size in the minority (home) language.

What the Researchers Did

- The researchers tested 69 children from Turkish or Moroccan (Tarifit) descent living in the Netherlands. The children were tested three times, with one year between each measurement. At the first testing time, the children were 5.5 years old on average.
- At each testing time, the researchers gathered several measures for each child, including information on visuospatial working memory, selective attention, executive attention, receptive vocabulary size in the majority language (Dutch) and in the home language (Turkish or Tarifit).
- The researchers also gathered additional information on the children's intelligence, verbal short-term memory, and the educational level of their parents.
- By using all measures in analyses, the researchers were able to focus on the relationship between cognitive ability (in terms of attention and memory measures) and vocabulary size and to rule out other potential explanations.

What the Researchers Found

- Children who scored better on the cognitive tests knew more Dutch words one year later than their peers who scored lower on the cognitive tests.

- Not all cognitive abilities were equally important for vocabulary development. The children's scores on the two attention tests predicted their Dutch vocabulary whereas their working memory scores did not.
- For vocabulary size in the home language, it was irrelevant whether children scored high or low on the cognitive tests.
- Vocabulary size in Dutch grew steadily over two years, in contrast to the children's home language vocabulary. In particular, the Tarifit vocabulary development of the children from Moroccan descent showed stagnation.

Things to Consider

- While the children's Dutch vocabulary continued to increase, their vocabulary size in the minority language showed a less stable development. Immigrant children learn the minority language mostly in the home context whereas the majority language is linked to the school context. Therefore, learning vocabulary in school at later ages might be more dependent on attentional processes than learning vocabulary at home at younger ages.
- Majority and minority languages seem to be driven by different development dynamics. More research is needed with different migrant populations and language pairs to confirm this conclusion. Further research should also tease apart if immigrants' age, learning context, or both influence the role of attention in children's vocabulary development.

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