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Phonotactic probability effect in nonword recall and its relationship with vocabulary in monolingual and bilingual preschoolers

Marielle H. Messer *, Paul P.M. Leseman, Jan Boom, Aziza Y. Mayo

Langeveld Institute, Utrecht University, 3508 TC, Utrecht, The Netherlands

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A B S T R A C T

The current study examined to what extent information in long-term memory concerning the distribution of phoneme clusters in a language, so-called long-term phonotactic knowledge, increased the capacity of verbal short-term memory in young language learners and, through increased verbal short-term memory capacity, supported these children's first and second language vocabulary acquisition. Participants were 67 monolingual Dutch and 60 bilingual Turkish–Dutch 4-year-olds. The superior recall of nonwords with high phonotactic probability compared with nonwords with low phonotactic probability indicated that phonotactic knowledge was supportive for verbal short-term recall in both languages. The extent of this support depended on prior experiences with the language: The Turkish–Dutch children showed a greater phonotactic probability effect in their native language Turkish compared with their Dutch peers, and the monolingual Dutch children outperformed the bilingual Turkish–Dutch children in their native language Dutch. Regression analyses showed that phonotactic knowledge, indicated by the difference in recall of nonwords with high versus low phonotactic probability, was an important predictor of vocabulary in both languages.

* Corresponding author. Fax: +31 0 302537731.
E-mail address: m.h.messer@uu.nl (M.H. Messer).

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Introduction

Verbal short-term memory plays a crucial role in the acquisition of both native and second language skills. Increasing evidence suggests that the capacity of verbal short-term memory is influenced by long-term knowledge. Until recently, it was believed that the source of this long-term memory influence is purely lexical–semantic. However, Thorn and Frankish (2005) demonstrated an additional contribution of long-term knowledge concerning the distribution of phoneme clusters in a language, so-called long-term phonotactic knowledge. Although they demonstrated this influence in an adult population, the question arises whether this finding also holds for young language learners. Furthermore, it is not yet clear whether this specialized phonotactic knowledge that supports native language acquisition also supports the acquisition of a second language with a different distribution of phoneme clusters. The aim of the current study was to investigate these questions by determining whether long-term phonotactic knowledge support is also found for 4-year-olds who are either Dutch native speakers or Turkish native speakers learning Dutch as a second language. For most Turkish immigrant children in The Netherlands, Turkish is their home language and school enrollment often marks their first full submersion in a primarily Dutch language environment. The special interest in this group follows from the persistent disadvantages in Dutch language and literacy development compared with native Dutch children at the start of primary school (Aarts & Verhoeven, 1999; Leseman, 2000; Leseman & De Jong, 1998; Leseman & Van den Boom, 1999; Sociaal en Cultureel Planbureau [SCP], 2007). We hypothesize that Turkish–Dutch children have more difficulty in remembering novel phonological forms in Dutch because they have less support from entrenched phonotactic knowledge of Dutch, thereby hindering their Dutch vocabulary development.

A number of studies have shown that individual differences in the capacity of verbal short-term memory, often referred to as the phonological loop, predict language acquisition (e.g., Baddeley, Gathercole, & Papagno, 1998; Gathercole, 2006; Gathercole, Service, Hitch, Adams, & Martin, 1999b; Gathercole, Willis, Emslie, & Baddeley, 1992; Majerus, Poncelet, Greffe, & Van der Linden, 2006). Measures of verbal short-term memory span, such as digit and nonword recall, have been found to strongly correlate with different aspects of language development, including receptive vocabulary knowledge, vocabulary specificity, mean length of utterances, and syntactic diversity (Adams & Gathercole, 2000). This is the case not only for native language acquisition but also when learning a foreign language (e.g., Cheung, 1996; O'Brien, Segalowitz, Collentine, & Freed, 2006; Service, 1992; Service & Kohonen, 1995). The ability to maintain sound patterns in memory for a short period of time while constructing long-term representations apparently is necessary for language acquisition.

Within the widely used working memory model of Baddeley and Hitch (1974), the phonological loop is thought to consist of two components: a storage component, where incoming verbal information is stored temporarily in a phonological form, and a subvocal rehearsal system that refreshes information in the loop to prevent decay. The different components of the working memory model have been shown to be already at place in children between 4 and 6 years of age (Alloway, Gathercole, Willis, & Adams, 2004). For children, the loop capacity grows rapidly. Traditionally, it was thought that the growth in articulation rate, which enhances subvocal rehearsal and recall speed during output, was responsible for the growth in the capacity of the phonological loop. However, this mechanism does not suffice to explain the substantial growth over the first years of life because there are indications that subvocal rehearsal is present only from the age of 7 years onward and the capacity does grow before this age (Baddeley et al., 1998). A second, and perhaps more powerful, proposed mechanism of growth is the use of more permanent knowledge representations in long-term memory to support short-term recall. Language knowledge, which grows rapidly in young children, is thought to be employed in the phonological store to reconstruct blurred memory traces, a process referred to as redintegration or pattern completion (Brown & Hulme, 1995; Hulme et al., 1997; Thorn, Gathercole, & Frankish, 2005). Following this line of reasoning, the influences between language knowledge and the phonological store are bidirectional; developing language knowledge supports verbal short-term recall, increasing the capacity to remember novel phonological forms and thereby the effectiveness of verbal short-term memory for acquiring new structures of that language.

There is increasing evidence that verbal short-term recall is indeed influenced by long-term memory. One source of evidence is the frequently demonstrated lexicality effect; memory performance is superior for words over nonexisting words (i.e., nonwords for which there are no representations in the mental lexicon) even when articulatory duration and phonotactic frequency are identical (Hulme, Maughan, & Brown, 1991). A second source of evidence showing the support of available language knowledge is provided by the finding that nonwords based on the native language are recalled better than nonwords based on a less familiar or unfamiliar language, an effect referred to as the language familiarity effect (Thorn & Gathercole, 1999; Thorn, Gathercole, & Frankish, 2002). A final source of evidence, perhaps underlying this language familiarity effect, is the so-called wordlikeness effect that has been found for children as well as adults. Nonwords rated by native speakers as sounding language-like are recalled better than language-unlike nonwords (Gathercole, Frankish, Pickering, & Peaker, 1999a). The same holds for statistical measures of wordlikeness; nonwords constructed of highly frequent phoneme clusters are recalled better than nonwords constructed of infrequent phoneme clusters, an effect found with children as young as 3.6 years of age (Coady & Aslin, 2004; Roodenrys & Hinton, 2002; Thorn & Frankish, 2005).

The precise source of the long-term memory support for nonword recall is still disputed. Roodenrys and Hinton (2002) proposed that only lexical–semantic knowledge is used as support in nonword recall. According to them, even though there are no representations of nonwords in the mental lexicon, support could come from known real words that are highly similar to the nonword but that differ in one phoneme, so-called neighbor words. However, in a recent study, Thorn and Frankish (2005) demonstrated that, in addition to lexical–semantic knowledge, sublexical knowledge of the statistical distribution of phoneme clusters in a language, referred to as the phonotactics of that language, is used for support. When controlling for neighborhood size in a more precise way than Roodenrys and Hinton (2002) did, nonwords composed of highly frequent phoneme clusters were recalled better than those consisting of infrequent clusters. Furthermore, a study using incidental phonotactic learning showed that nonwords following the phonotactic rules of a previously learned artificial language were recalled better than nonwords illegal to this artificial language (Majerus, Van der Linden, Mulder, Meulemans, & Peters, 2004). Thus, it seems likely that not only lexical–semantic knowledge but also phonotactic knowledge influences verbal short-term recall.

The aforementioned studies, which carefully distinguished the influence of lexical–semantic knowledge from phonotactic knowledge on verbal short-term recall, were conducted with monolingual populations only. However, this distinction might be even more important in the case of second language acquisition. Whereas lexical–semantic knowledge of a native language could facilitate verbal short-term recall in a new language because conceptual representations can be at least partly shared (e.g., Francis, 2005), phonotactic knowledge of a native language is perhaps less supportive for recall in a new language because the distribution of phoneme clusters is more language specific, making transfer of knowledge to the new language difficult. However, if the phonotactics of languages overlap to some extent, sharing not only the majority of phonemes but also the frequency of occurrence of certain phoneme clusters in speech, there might also be transfer on the phonotactic level (Ellis & Beaton, 1993).

Already at 9 months of age, monolingual children show preferences for phoneme clusters that characterize their native language and for nonwords with high phonotactic probabilities compared with infrequent nonwords (Jusczyk, Luce, & Charles-Luce, 1994). Infants use this distributional knowledge to identify individual words in a speech stream (Mattys & Jusczyk, 2001), an ability related to later vocabulary and grammatical skills during the preschool age (Newman, Bernstein Ratner, Jusczyk, Jusczyk, & Dow, 2006). One of the few studies investigating phonotactics in bilinguals showed that the native language influences the acquisition of phonotactics in the second language (Sebastian-Galles & Bosch, 2002). Nonwords that were either phonotactically legal or illegal in Catalan and always illegal in Spanish were presented to bilingual Spanish Catalan 10-month-olds and bilingual adults who had acquired their second language between 3 and 4 years of age. Whereas the Catalan-dominant infants showed preference for the nonwords that were legal in Catalan, the Spanish-dominant bilingual infants did not. Interestingly, the same pattern of results was found with adults. Thus, Spanish-dominant adult bilinguals were able to acquire most aspects of Catalan phonotactics, but even after extensive exposure to the language, phonotactic structures that were illegal in their native language were not acquired. Also, on the level of phonemes, it has been shown that sensitivity for nonnative phonetic contrasts declines during infancy (e.g., Werker & Tees, 2002) and that early language experience impedes the acquisition of nonnative phonemes during adulthood (Iverson et al., 2003). These findings indicate that from a young age onward, the knowledge base specializes in the phonotactic probabilities of the native language, making it highly efficient for native language acquisition, but delaying or even partly impeding the development of phonotactic knowledge and thereby short-term memory for a foreign language.

The current study aimed to investigate to what extent knowledge of the phonotactics of a particular language influences short-term memory in that language in young children with varying previous exposure to that language. The study involved a sample of 4-year-old monolingual Dutch native and bilingual Turkish–Dutch immigrant children who had just enrolled in the kindergarten department of primary school. The Dutch 4-year-olds were presumed to have age-appropriate knowledge of Dutch, having been exposed to predominantly Dutch home and preschool environments for several years. The Turkish–Dutch children were raised bilingually. Turkish was their first language and the language they were exposed to most at home. They were presumed to have comparatively extensive and well-entrenched knowledge of Turkish. Dutch was their second language, provided to some extent at home and in addition in preschool settings before the age of 4 years. Therefore, the Turkish–Dutch children were presumed to have some knowledge of Dutch, but it was less extensive and well-entrenched than their knowledge of Turkish. To investigate the influence of phonotactic knowledge on verbal short-term memory, using nonword recall tasks, nonwords were constructed with either high or low phonotactic probability in both Dutch and Turkish. If phonotactic knowledge influences verbal short-term memory, recall should be better for nonwords with high phonotactic probability than for nonwords with low phonotactic probability. Furthermore, by comparing the bilingual and monolingual children in both languages, it would be possible to determine whether differences in prior experience with a language influenced the magnitude of the phonotactic probability effect. More specifically, a comparatively large phonotactic probability effect was expected for Dutch children in Dutch and for Turkish–Dutch children in Turkish. A smaller phonotactic probability effect was expected for Turkish–Dutch children in Dutch because they had at least some experience with Dutch. Moreover, no phonotactic probability effect was expected for Dutch children in Turkish because they had hardly any experience with Turkish. Support of verbal short-term memory by phonotactic knowledge is seen as an important mechanism in language learning in addition to lexical support. The current study, therefore, also addressed the question of to what extent phonotactic knowledge, indicated by the difference in recall of nonwords with high versus low phonotactic probability, predicted vocabulary.

Method

Participants

A sample of 127 children who just started Dutch kindergarten at the age of 4 years participated in this study. The Turkish–Dutch group consisted of 60 children with Turkish as their native language, learning Dutch as a second language (32 boys and 28 girls, mean age = 52.5 months, *SD* = 3.2, range = 49–66). The Dutch group consisted of 67 children from predominantly Dutch-speaking homes with Dutch as their first and strongest language (44 boys and 23 girls, mean age = 52.1 months, *SD* = 2.8, range = 48–62).

Inner-city Dutch primary schools with a moderate to high percentage of ethnic minority children (25–100%) and with Dutch as the language of schooling were approached. A total of 31 schools were willing to participate, yielding a positive response rate of 35%, which is common for this type of research in The Netherlands. The main reason given not to participate was expected workload. The primary caregivers of the children were administered a screening questionnaire to ensure that the language interactions with the target child in the family context were at least 75% Turkish in the first group and 75% Dutch in the latter group. Because of these restrictions, the positive response rates were 69% for the Turkish–Dutch group and 80% for the Dutch group. Most of the primary caregivers in the Turkish–Dutch group were born in Turkey (83%) and on average had lived in The Netherlands for

14.7 years (range = 0.5–30). Parental consent was obtained for each participating child. An additional 12 children were tested but could not be included in the final sample due to testing difficulties typical for this young age (7 Turkish–Dutch and 4 Dutch children) or attrition due to having moved away when vocabulary was measured 1 year later (attrition rate = 0.7%).

Questionnaires, administered to the primary caregivers to assess the linguistic environment of the children, revealed that the Turkish–Dutch children were already exposed to the Dutch language before their introduction to kindergarten. Most children had attended some form of early childhood care and education providing a Dutch immersion context (88% of the Turkish–Dutch group and 90% of the Dutch group, average = 4 half days per week, no statistically significant difference between the groups) and had older siblings who sometimes or always communicated in Dutch with the children (65% of the Turkish–Dutch group, average = 1.6, range = 1–4, and 31% of the Dutch group, average = 1.8, range = 1–4).

Procedure

Trained research assistants, who were fluent in the native and second languages of the children, tested each child individually in a quiet place at school. Testing took place on 2 separate days, on average 1 week apart. Each testing session lasted for approximately 75 min, including play breaks and tests that were part of another study. The tests were administered in a fixed order. The order of the tests that are reported in the current study was for the native Dutch children: Dutch vocabulary, nonword recall Dutch high phonotactic probability, Raven, word recall Dutch, dot matrix, and nonword recall Turkish low phonotactic probability (Day 1); digit recall, nonword recall Dutch low phonotactic probability, and nonword recall Turkish high phonotactic probability (Day 2). The order of tests for the Turkish–Dutch children was as follows: Turkish vocabulary, Dutch vocabulary, nonword recall Turkish high phonotactic probability, Raven, word recall Turkish, word recall Dutch, dot matrix, and nonword recall Dutch low phonotactic probability (Day 1); digit recall, nonword recall Turkish low phonotactic probability, and nonword recall Dutch high phonotactic probability (Day 2). To keep them motivated, children were rewarded with a small token after each test.

Measures

Nonword recall

The nonword recall test of the Automated Working Memory Assessment (AWMA) battery (Alloway, 2007) was translated and voice-recorded into Turkish and Dutch by native speakers. Participating children needed to repeat voice-recorded monosyllabic nonwords in lists of increasing length, starting with a block of one nonword and building up to a block of five nonwords in a row (see Appendix A for the nonwords). Each block consisted of six trials. A trial was rewarded with a score of 1 when none of the nonwords was omitted, when the sequence of nonwords was correct, and when each nonword was recalled correctly. Each phoneme of a nonword needed to be recalled correctly for a positive score, with the exception of consistently substituted phonemes resulting from articulation problems. With a total of six trials per block, the maximum score per block was 6. When the first four trials within a block were recalled correctly, the child automatically received a score of 6 and proceeded to the next block. Testing stopped after three incorrect recalls within one block. Note that a score of 6, for example, could represent six correct one-nonword trials and no correct two-nonword trials or four correct one-nonword trials and two correct two-nonword trials. The scores could range from 0 (Block 1) to 30 (Block 5), but none of these young children exceeded Block 3 (maximum score = 18). Each test started with a short practice session. The nonword recall tests were videotaped for scoring purposes.

To determine whether phonotactic knowledge influences verbal short-term recall, four sets of nonwords were created and incorporated into the AWMA battery, resulting in four tasks sharing the same format and scoring rules. Nonwords were like either normal Dutch or normal Turkish words in terms of phonemes used; however, both sets were further subdivided into nonwords containing highly frequent biphones (high phonotactic probability) or infrequent biphones (low phonotactic probability) in their respective languages (Dutch and Turkish). After data collection, native speakers rechecked all scores using the video recordings. In case of disagreement on more than half of the trials within a block, a third score check by the principal investigator was decisive (6% of the tasks).

The following steps were taken to construct the nonwords of both languages in a highly similar manner. Because to our knowledge no comparable corpora were available for Turkish and Dutch, and because both Dutch and Turkish are very transparent languages (De Jong & Van der Leij, 1999; Durgunoğlu, 2006) and thus allowed the use of orthographic information, we created equivalent corpora from cross-translated Turkish and Dutch novels (see Appendix B for details of the corpora). Native speakers used biphone frequency counts to construct nonwords with high phonotactic probability (composed of highly frequent biphones) and nonwords with low phonotactic probability (composed of lowly frequent biphones). A computer program was developed to perform frequency counts in the corpora.

Bigram frequencies were calculated by adding the relative frequencies (per 10,000) of each word form in the corpus containing the bigram. Trigram frequency counts were used to correct for diphthongs in the Dutch language. Counts were based on word forms instead of lemmata because Turkish is an agglutinating language and thus lemma counts would imply a substantial loss of phonological information. Summated bigram frequency was then calculated by totaling the frequencies of each bigram in a nonword. Table 1 shows all characteristics of the nonwords. One-way analyses of variance (ANOVAs) affirmed that the high phonotactic probability nonwords had significantly higher summated biphone frequencies than the low phonotactic probability nonwords for both Turkish, $F(1, 70) = 129.4$, $p < .01$, and Dutch, $F(1, 70) = 113.7$, $p < .01$. To minimize lexical influences, neighborhood size was kept down for all nonwords. The neighborhood size of each nonword was computed by adding up the relative frequencies (per 10,000) of all word forms in the corpus that could be obtained by substituting one phoneme of the nonword. There were no statistically significant differences between the two nonword types.

Because our corpora were small, we validated the bigram frequency counts and neighborhood size of the Dutch nonwords in the larger CELEX database using WordGen software (Duyck, Desmet, Verbeke, & Brysbaert, 2004). Unfortunately, a similar check was not possible for the Turkish nonwords because, to the best of our knowledge, a comparable large Turkish database was not available. One-way ANOVA confirmed that the high phonotactic probability nonwords indeed had significantly higher summated biphone frequencies ($M = 20{,}096$) than the low phonotactic probability nonwords ($M = 3332$), $F(1, 70) = 55.5$, $p < .01$. Contrary to the results based on our own Dutch corpus, CELEX revealed a significant difference in neighborhood size between the two nonword types, $F(1, 70) = 4.7$, $p < .05$, with a larger total number of neighbor words for nonwords with high phonotactic probability (3.2) than for nonwords with low phonotactic probability (1.8). However, the effect size was very small ($\omega^2 = .05$). In addition, the neighborhood sizes of both types of nonwords were considerably smaller than the mean neighborhood sizes for three-, four-, and five-letter words found in the CELEX database that have been shown to be 14.7, 8.5, and 5.1, respectively (Duyck et al., 2004). Moreover, the additional words in the CELEX database that were not present in our Dutch corpus were probably very infrequent words that 4-year-olds have not acquired yet. Therefore, the possible lexical–semantic influences in nonword recall were considered to be negligible.

Table 1
Characteristics of nonwords with low or high phonotactic probability in Turkish and Dutch

Variable	Turkish		Dutch	
	Low-probability	High-probability	Low-probability	High-probability
Summated bigram frequency (relative frequency per 10,000)	32.4	542.6	26.6	442.0
Neighborhood size (relative frequency per 10,000)	0.3	3.0	0.1	0.2
Likeness rating (1–5)	2.2	2.5	2.6	3.6
Phonemes (n)	3.6	3.7	3.9	4.3
Articulation rate (s)	0.57	0.56	0.66	0.65

Note. Means are reported. Because no child exceeded Block 3, only the nonwords of the first three blocks were used to calculate the means ($n = 36$ for each type).

Independent ratings by native speakers also confirmed that the phonotactic probability manipulations were valid (Frisch, Large, & Pisoni, 2000). Two panels of native speakers (16 Dutch and 11 Turkish) rated the wordlikeness of each voice-recorded nonword in their own language, offered at random in blocks of 10, on a scale from 1 (*does not sound like a real Dutch/Turkish word at all*) to 5 (*sounds a lot like a real Dutch/Turkish word*). The nonwords in the high phonotactic probability list sounded more like real words to the native speakers than the nonwords in the low phonotactic probability list for both Turkish, $F(1, 70) = 4.4$, $p < .05$, and Dutch, $F(1, 70) = 37.4$, $p < .01$.

Finally, the length and articulation rate of the nonwords were checked to control for possible confounding influences (see, e.g., Vitevitch & Luce, 2005). The number of phonemes (and thus consonant clusters) did not differ between the types in Turkish. In Dutch, the nonwords with high phonotactic probability were slightly longer than the nonwords with low phonotactic probability, $F(1, 70) = 5.7$, $p < .05$, and thus were possibly more difficult to remember. Because this effect would work against the hypothesis, it was not expected to bias the conclusions of the current study. After data collection, the video recordings of 20 randomly selected children (10 Dutch and 10 Turkish) were used to measure the pronunciation time of each nonword from their audio traces. The differences in articulation rate between the two nonword types were very small and statistically nonsignificant.

Vocabulary

The Turkish and Dutch receptive vocabulary tests were part of the Test for Bilingualism (Toets Tweetaligheid) (Verhoeven, Narain, Extra, Konak, & Zerrouk, 1995), a language test kit specifically designed for research into bilingual development and examined for cultural bias on item level. The test was presented on a laptop computer using the software package MINDS (Brand, 1999). Four line drawings were presented on the computer screen, and the children were asked to point to the one corresponding to the word spoken by the research assistant. The test started with a short practice session. To avoid fatigue, the test was divided into 30 odd items for the Turkish version and 30 even items for the Dutch version, resulting in two parallel tests without conceptual overlap. Although the vocabulary test was a standardized and widely used test, the results showed a bimodal distribution in the Turkish version. To strengthen measurement quality, we decided to measure vocabulary again 1 year later. This time, both halves of the test were administered in both languages with 2 weeks in between. To avoid ceiling effects, the Dutch version was extended with 15 items from a parallel Dutch test designed from the same item pool but for a broader age range (Taaltoets Alle Kinderen) (Verhoeven & Vermeer, 2001). Each correct answer was rewarded with a score of 1. Testing was stopped when children failed on five consecutive items, after which the remaining items were rewarded with the chance score of 0.25. Therefore, the scores could range from 0 to 30 at Time 1 and from 0 to 30 (Turkish version) and 0 to 45 (Dutch version) at Time 2. The mean of the vocabulary scores at Time 1 and Time 2 was computed for each group and each language separately after z-transformation of the scores. For the Turkish language, only vocabulary at Time 2 was used. Cronbach's alpha for the receptive vocabulary test ranged from .73 to .88 at Time 1 and Time 2 for the two groups separately.

Control measures

Verbal short-term memory. In addition to nonword recall, two other tests of the AWMA battery (Alloway, 2007), digit recall and word recall, were used to assess verbal short-term memory. The tests were translated and voice-recorded into Turkish and Dutch by native speakers. Participating children needed to repeat voice-recorded verbal items in lists of increasing length, starting with a block of one item and building up to a block of seven items in a row. Each block consisted of six trials that were scored as incorrect when one of the items was omitted, when the sequence of items was incorrect, or when an item was recalled wrongly. When the first four trials within a block were recalled correctly, the child automatically received a score of 6 and proceeded to the next block. Testing stopped after three incorrect recalls within one block. The scores could range from 0 to 42. Each test started with a short practice session. Digit recall was tested in the native language with a random sequence of digits ranging from 0 to 9. Word recall was tested in Dutch and also in Turkish in the Turkish–Dutch group. To obtain highly frequent monosyllabic words with a low acquisition age in a similar manner for both languages, we created two equivalent corpora from cross-translations of children's books (see Appendix B for details). To the best of our knowledge, such comparable corpora were not available for

Turkish and Dutch. The stimuli consisted of nouns, adjectives, adverbs, color names, and verbs (stem in Dutch and imperative in Turkish). Native speakers ensured that the words were not too abstract for the children.

Visuospatial short-term memory. The capacity of visuospatial short-term memory was assessed with Dot Matrix, also a test of the AWMA battery (Alloway, 2007) that was translated and voice-recorded into Dutch and Turkish by native speakers. The child was presented with a 4×4 matrix on the computer screen. A red dot shortly appeared in one of the boxes, and the child needed to point out the correct box. The test started with a block of one dot, building up to a block with a sequence of seven dots presented across the matrix. Each block consisted of six trials that were scored as incorrect when one of the boxes was omitted, when the sequence of boxes was incorrect, or when a box was recalled wrongly. When the first four trials within a block were recalled correctly, the child automatically received a score of 6 and proceeded to the next block. Testing stopped after three incorrect recalls within one block. The scores could range from 0 to 42. The test started with a short practice session.

Nonverbal IQ. Raven's Colored Progressive Matrices (Raven, Raven, & Court, 1998) was administered to measure nonverbal fluid intelligence. The task was presented on a laptop computer using the software package MINDS (Brand, 1999). The children needed to decide which one of six pieces on the computer screen would best complete the visual pattern from which a piece was missing. Each correct answer was rewarded with a score of 1, yielding a total score between 0 and 36.

Results

Initial analysis

The data were first explored to check for outliers and missing data likely to be present in this young age group. For the Turkish sample, 1.7% of all administered tests were missing; for the Dutch sample, 1% of the tests were missing. Because missing value analysis revealed that the pattern of missing data was random, the missing data were imputed using the expectation maximization method. There were no extreme outliers when looking at each variable separately, so none of the cases was excluded from the analyses of variance. For the regression analyses, outliers greater than 2 standard deviations were excluded (Dutch group 4.5%, Turkish–Dutch group Dutch language 6.7%, and Turkish–Dutch group Turkish language 5%). Finally, to check whether all variables were normally distributed, standardized skewness and kurtosis measures were calculated for each variable in each group separately. The standardized skewness measures for Dutch and Turkish nonwords with low phonotactic probability in the Turkish group, and for nonverbal IQ and Turkish nonwords with low phonotactic probability in the Dutch group, exceeded two standard deviations. To correct for this, a square root transformation was applied on these measures after which the data were normally distributed. The corrected variables were used in the regression analyses and ANOVAs. In the latter case, the variables to which they were compared were also transformed (Dutch and Turkish nonwords with high phonotactic probability).

Control tasks

Table 2 presents the means and standard deviations for all measures. One-way ANOVAs for each variable separately revealed that the bilingual Turkish–Dutch group and monolingual Dutch group did not differ significantly on nonverbal IQ or on visuospatial short-term memory. Furthermore, there were no differences in verbal short-term memory as measured with digit recall in the native language. However, the Turkish–Dutch children did obtain lower verbal short-term memory scores as measured with word recall compared with the Dutch children not only in their second language, $F(1, 125) = 17.83$, $p < .01$, $\omega^2 = .34$, but also in their native language, $F(1, 125) = 10.01$, $p < .01$, $\omega^2 = .26$.

Table 2
Descriptive statistics of all measures for both groups

Variable	Turkish–Dutch group ($n = 60$)			Dutch group ($n = 67$)		
	M	*SD*	Observed range	*M*	*SD*	Observed range
Control measures						
Nonverbal IQ	12.3	2.6	5–19	12.1	3.2	6–22
Visuospatial recall	9.6	3.2	1–23	9.6	3.4	1–17
Digit recall	14.3	4.1	5–24	14.4	4.7	5–24
Word recall: Dutch	9.9	3.7	0–21	12.9	4.3	0–22
Word recall: Turkish	10.7	3.6	0–19			
Vocabulary						
Time1: Dutch	14.1	3.7	7.0–24.0	20.7	3.6	10.8–28.0
Time 1: Turkish	14.1	2.7	9.3–20.0			
Time 2: Dutch	20.0	3.1	14.0–26.5	27.5	4.2	17.9–35.0
Time 2: Turkish	18.0	2.5	10.5–24.0			
Nonword recall						
High-probability: Dutch	4.6	2.2	0–9	6.1	2.4	1–12
High-probability: Turkish	5.8	2.4	1–11	3.6	2.8	0–11
Low-probability: Dutch	2.7	1.9	0–9	4.0	2.6	0–11
Low-probability: Turkish	2.7	1.9	0–8	2.1	1.6	0–7

Vocabulary tasks

Vocabulary measures showed a similar pattern of differences (see Table 2), with the Turkish–Dutch children performing at a lower level not only for Dutch vocabulary at Time 1, $F(1, 125) = 103.72$, $p < .01$, $\omega^2 = .67$, and at Time 2, $F(1, 125) = 128.23$, $p < .01$, $\omega^2 = .71$, but also for their native language at Time 1, $F(1, 125) = 135.15$, $p < .01$, $\omega^2 = .72$, and at Time 2, $F(1, 125) = 232.12$, $p < .01$, $\omega^2 = .80$. Note that the Dutch and Turkish tests were constructed to be equivalent parallel tests.

Phonotactic probability effect in nonword recall

To examine whether phonotactic probability influenced verbal short-term recall, two-way repeated measures ANOVAs with group (Turkish–Dutch or Dutch) as a between-participants factor and phonotactic probability (high or low) as a within-participants factor were conducted for each language separately. The results are depicted in Table 2 and Fig. 1. The analyses established a significant main effect of phonotactic probability for both the Dutch language, $F(1, 125) = 77.75$, $p < .01$, and the Turkish language, $F(1, 125) = 54.28$, $p < .01$, indicating that nonwords with high phonotactic probability were recalled better than nonwords with low phonotactic probability. Furthermore, a significant main effect of group was present in both the Dutch language, $F(1, 125) = 11.25$, $p < .01$, and the Turkish language, $F(1, 125) = 23.07$, $p < .01$. In Dutch, the monolingual Dutch children outperformed the bilingual Turkish–Dutch children who were learning Dutch as their second language; in Turkish, the Turkish–Dutch children outperformed the Dutch children for whom the language was completely new. In the Turkish language, group interacted with phonotactic probability, $F(1, 125) = 9.28$, $p < .01$, as expected. The Turkish–Dutch children showed better recall of nonwords with high phonotactic probability ($M = 5.8$, $SD = 2.4$) compared with their Dutch peers ($M = 3.6$, $SD = 2.8$), whereas both groups showed similar recall for nonwords with low phonotactic probability (Turkish–Dutch group $M = 2.7$, $SD = 1.9$, Dutch group $M = 2.1$, $SD = 1.6$). A similar interaction effect was expected in the Dutch language. However, the results revealed that the Turkish–Dutch children had also more difficulty in recall of nonwords with low phonotactic probability ($M = 2.7$, $SD = 1.9$) compared with the Dutch children ($M = 4.0$, $SD = 2.6$). Another unexpected finding was the small but significant phonotactic probability effect on Dutch children's recall of Turkish nonwords. Dutch children, who did not have any substantial experience with the Turkish language, showed greater recall of Turkish nonwords with high-probability ($M = 3.6$, $SD = 2.8$) than of Turkish nonwords with low phonotactic probability ($M = 2.1$, $SD = 1.6$), although the effect was much smaller than that for the Turkish–Dutch children ($M = 5.8$, $SD = 2.4$ and $M = 2.7$, $SD = 1.9$, respectively).

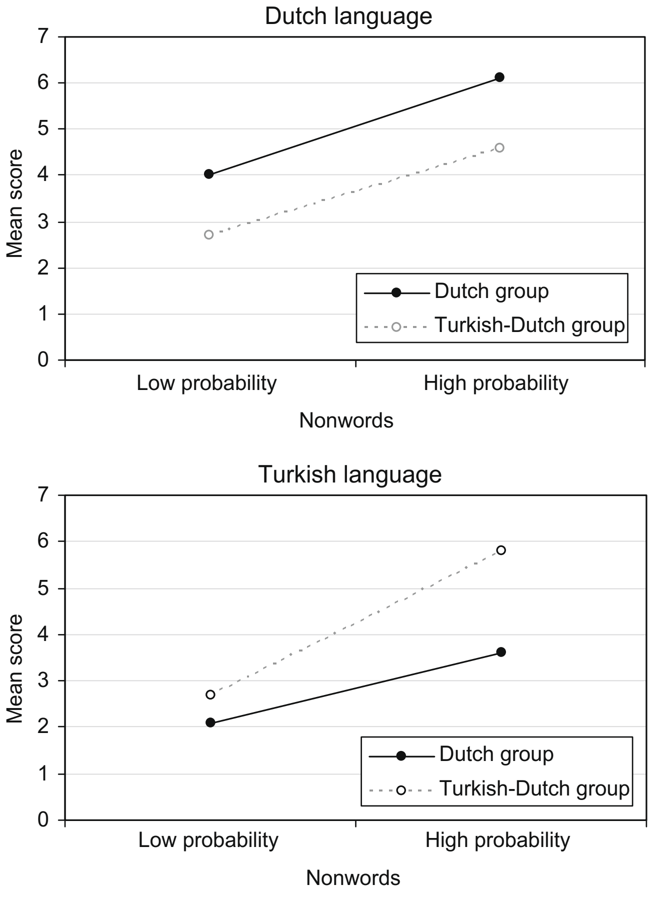

Fig. 1. Turkish–Dutch and Dutch children's recall of nonwords with low phonotactic probability (low-probability) and nonwords with high phonotactic probability (high-probability) in the Dutch and Turkish languages.

Nonword recall, word recall, and vocabulary

Hierarchical regression analyses were used to determine to what extent recall of nonwords with low phonotactic probability, recall of nonwords with high phonotactic probability, and recall of words predicted vocabulary, controlling for nonverbal IQ. The three measures of verbal short-term memory were assumed to reflect different degrees of support by long-term language knowledge. The order of entry of the three measures in the regression equation was based on this assumption. The most pure measure of verbal short-term memory, free of long-term phonotactic knowledge as well as lexical–semantic knowledge support, was entered first to assess whether differences in a general capacity to remember sound structures predicted differences in vocabulary. Subsequently, adding nonwords with high phonotactic probability to the model estimated whether the capacity to remember highly frequent sound structures, for which knowledge of phonotactics could be used as support, was important for vocabulary development. Finally, adding the measure of word recall, for which both phonotactic and lexical–semantic knowledge could be used as support, to the model estimated whether additional lexical–semantic knowledge was important for vocabulary development. The results of the regression analyses are presented in Table 3.

To control for possible differences in nonverbal IQ, this variable was entered as a first step in the regression analyses. Only in the Dutch group did nonverbal IQ significantly predict vocabulary (R^2

Table 3
Hierarchical regression analyses for three measures of verbal short-term memory predicting vocabulary in the native and second languages after controlling for nonverbal IQ

Predictor	Turkish–Dutch group				Dutch group	
	Turkish vocabulary ($n = 57$)		Dutch vocabulary ($n = 56$)		Dutch vocabulary ($n = 64$)	
	β	ΔR^2	β	ΔR^2	β	ΔR^2
Step 1		.01		.00		.16**
Nonverbal IQ	−.09		.02		.40**	
Step 2		.02		.20**		.10**
Nonverbal IQ	−.08		.01		.40**	
Nonword low-probability	−.13		.45**		.32**	
Step 3		.10*		.11**		.17**
Nonverbal IQ	−.07		−.00		.36**	
Nonword low-probability	−.15		.25		.13	
Nonword high-probability	.31*		.38**		.45**	
Step 4		.18**		.04		.04*
Nonverbal IQ	−.04		.01		.33**	
Nonword low-probability	−.23		.25		.09	
Nonword high-probability	.10		.31*		.42**	
Word	.49*		.20		.22*	
R^2 total		.30**		.34**		.47**

* $p < .05$.
** $p < .01$.

change = .16, $p < .01$). Recall of nonwords with low phonotactic probability in Dutch, entered in the second step of the regression analyses, predicted Dutch vocabulary in both groups (R^2 change = .10–.20, $ps < .01$), indicating that a general capacity to remember sound structures was related to vocabulary test scores. However, in the Turkish language, this effect was not found. When controlling for nonwords with low phonotactic probability, recall of nonwords with high phonotactic probability, entered in the third step, significantly predicted vocabulary in all three analyses (R^2 change = .10–.17, $ps < .05$), suggesting that the capacity to remember highly frequent sound structures is important for native and second language vocabularies. When adding recall of words as a final step, additional variance was explained only in the native language of both groups (R^2 change = .04–.18, $ps < .05$), showing that not only the capacity to remember sound structures but also the additional lexical–semantic component was positively related to vocabulary. In the final model, word recall, comprising both phonotactic and lexical–semantic knowledge, was the only significant predictor of Turkish vocabulary. For Dutch vocabulary in both groups, recall of nonwords with high phonotactic probability, requiring phonotactic but not lexical–semantic knowledge, was the most important predictor. In total, 30–47% of variance in vocabulary skills was accounted for by nonverbal IQ and these three measures of verbal short-term memory.

Discussion

In the current study, we hypothesized that young children's knowledge of the phonotactic structure of a particular language influences their verbal short-term memory in that language. It was argued that if knowledge of the phonotactic structure of a language influences verbal short-term memory in that language, recall should be greater for nonwords with high phonotactic probability than for nonwords with low phonotactic probability in that language. The influence of prior language experience on this effect was studied by comparing nonword recall of monolingual Dutch children and bilingual Turkish–Dutch immigrant children in both Dutch and Turkish. It was predicted that the monolingual Dutch children, by virtue of their greater knowledge of the phonotactics of Dutch due to far more extensive exposure, would show a stronger effect of phonotactic probability in nonword recall in Dutch than would bilingual Turkish–Dutch children. Conversely, it was predicted that

Turkish–Dutch children, by virtue of their greater knowledge of Turkish phonotactics, would show a stronger phonotactic probability effect in nonword recall in Turkish than would Dutch children. In addition, Turkish–Dutch children were expected to show a phonotactic probability effect in Dutch because of the fact that Turkish–Dutch children, being bilingual, have been exposed to Dutch. But for Dutch children, we expected no phonotactic probability effect at all in Turkish because Turkish was an unfamiliar language for them. Moreover, no differences in nonword recall were expected between the groups with regard to nonwords with low phonotactic probability in either language. Finally, we examined to what extent phonotactic knowledge support in verbal short-term memory was related to children's vocabulary.

Phonotactic probability effect in nonword recall

To study the effect of phonotactic knowledge on verbal short-term memory, we developed nonword recall tasks with nonwords of either high or low phonotactic probability. The difference in phonotactic probability, based on high versus low frequency of the phoneme clusters used to construct the nonwords, proved to be valid and perceivable by native speakers (Frisch et al., 2000). Moreover, the neighborhood size of the constructed nonwords was very low (Thorn & Frankish, 2005), and the articulation rate, the number of phonemes, and the number of consonant clusters either did not differ between the two types of nonwords or would attenuate the expected phonotactic probability effect. In view of this, the main results of the study can be seen as supporting the hypothesis; Dutch children showed a clear phonotactic probability effect in Dutch, and Turkish–Dutch children showed a clear phonotactic probability effect in Turkish, indicating that sublexical knowledge supports nonword recall. Given the low neighborhood size of the nonwords, the language likeness effects in nonword recall cannot be attributed to lexical–semantic support by neighbor words in the mental lexicon, as has been suggested by others (Roodenrys & Hinton, 2002). The current study extends the findings of Thorn and Frankish (2005) with monolingual adult participants by showing that the phonotactic probability effect is already present at a young age.

Influence of prior language experience

The second hypothesis of the study, namely that the magnitude of the phonotactic probability effect depends on prior experiences with the language, was partially supported. If knowledge of the distribution of phoneme clusters in a particular language, phonotactic knowledge, supports nonword recall, an interaction effect of group (monolingual vs. bilingual) with phonotactic probability would be expected for both languages, with the two groups performing equally well on the low-probability nonwords in both languages and showing greater recall of the high-probability nonwords as a result of their language experience. Therefore, the monolingual Dutch children, being raised in Dutch from birth onward, were expected to show a phonotactic probability effect in the Dutch language only because Turkish is a new language for them. The bilingual Turkish–Dutch children, who spoke predominantly Turkish at home and started learning Dutch at a later age and less intensively via older siblings and enrollment in preschools, were expected to show a phonotactic probability effect in both languages but, compared with their Dutch peers, a stronger effect in Turkish and a less strong effect in Dutch. The results partly confirm these hypotheses. Indeed, in the Turkish language, the expected interaction effect was established, with the Turkish children showing a greater phonotactic probability effect in their native language compared with their Dutch peers. In the Dutch language, the Dutch children outperformed the Turkish–Dutch children. However, unexpectedly, there was no interaction effect due to the fact that the Dutch children also scored higher than the Turkish–Dutch children in recall of nonwords with low phonotactic probability.

A possible explanation is that the phonotactic knowledge of the Dutch children is more extensive and entrenched due to a longer period of language input, supporting even the storage of relatively infrequent phoneme clusters (Edwards, Beckman, & Munson, 2004; Ellis, 2002), an advantage that is not available to Turkish–Dutch children for whom Dutch is their second language. The fact that a similar advantage in recalling phonotactically low-probability nonwords was not found for the Turkish–Dutch children in Turkish can perhaps be explained by the comparatively less well-entrenched knowledge of Turkish due to the bilingual situation. However, a more plausible explanation is that the Turkish low-probability nonwords used in this study were less language-like than the Dutch low-probability nonwords, as indicated by lower ratings of wordlikeness by the native speakers in the panel check. Thus, the greater recall of Dutch low-probability nonwords by Dutch children compared with the Turkish–Dutch children does not necessarily refute the main hypothesis of the current study.

A second unexpected finding was that the monolingual Dutch children, who had no prior experience with the Turkish language, showed a phonotactic probability effect in Turkish, although it was much smaller than that for the Turkish children. Even though we cannot completely rule out the possibility that Dutch children have encountered the Turkish language through peers, a more plausible explanation for this effect seems to be a possible transfer of knowledge between the languages (Ellis & Beaton, 1993). The current study was not designed to further disentangle these cross-linguistic sources of phonotactic support, but tentative conclusions can be drawn from additional analyses. Further exploration of the lists of biphone frequencies in Turkish and Dutch, extracted from the corpora that were constructed for the current study, yielded a correlation of $r = .48$ ($p < .001$), indeed suggesting considerable overlap of phoneme clusters between the two languages. Additional cross-linguistic exploration of the nonwords[1] revealed that the nonwords with high phonotactic probability in Turkish indeed also had higher phonotactic probability in Dutch. Thus, the Dutch children could partly use their Dutch phonotactic knowledge to support their recall of high-probability Turkish nonwords. In the case of Dutch nonwords, further exploration revealed no differences in Turkish phonotactic probability. Thus, the Turkish–Dutch children probably did not have additional support in Dutch nonword recall from their knowledge of Turkish.

Taken together, the fact that the Turkish–Dutch children showed a greater phonotactic probability effect in their native language Turkish compared with their Dutch peers and the fact that the monolingual Dutch children outperformed the bilingual Turkish–Dutch children in their native language Dutch are in agreement with the hypothesis that phonotactic knowledge influences verbal short-term recall. The more input a child has received in a particular language, the more entrenched the phonotactic knowledge base of that language is in the child and the more support there is to sustain new aspects of that language in memory for short periods of time while constructing long-term representations.

Bilingual children's phonotactic knowledge support

The Turkish–Dutch children had some support of phonotactic knowledge in Dutch, but performance was far below that of the Dutch children. Because the Turkish–Dutch and Dutch children did not differ in nonverbal intelligence, visuospatial short-term recall, and verbal short-term recall for highly automated digit knowledge, it is not likely that these group differences can be attributed to differences in general cognitive abilities. These results suggest that because of a disadvantage at the very basic level of phonotactic knowledge acquisition, the Turkish-dominant bilingual children had more difficulties with sustaining new aspects of the Dutch language in their memory for short periods of time and, as a result, were hampered in their construction of long-term representations. Because phonotactic knowledge starts to develop during infancy and is language specific (Jusczyk et al., 1994), it could be that the specialized knowledge of the native language impedes short-term memory in the second language, as was argued in the Introduction of the current study. In line with this argument, a study with bilinguals showed that even after extensive exposure to a language, phonotactic structures that were illegal in the first language were not acquired (Sebastian-Galles & Bosch, 2002). In

[1] As a further check, the Dutch high- and low phonotactic probability nonwords were examined for phonotactic probability in our Turkish corpus, and the Turkish nonwords were examined in our Dutch corpus. Approximate cross-linguistic diphone frequencies were derived by changing the Dutch graphemes into the phonetically best corresponding Turkish graphemes in the following way: aa = ağ, ai = ay, c = k, dj = c, tj = ç, ee = eğ/iğ, i = i (end of word), j = y, zj = j, oo = oğ, sj = ş, u = ı, uu = ü, v = v (end of syllable), w = v (beginning of syllable), eu = ö, oe = u, and ie = i (except when end of word). One-way ANOVAs revealed a significant difference in cross-linguistic phonotactic frequency for the Turkish nonwords, with a higher Dutch phonotactic probability count for the Turkish high-probability nonwords ($M = 112.0$) compared with the Turkish low-probability nonwords ($M = 27.2$), $F(1, 70) = 9.6$, $p < .01$. The Dutch nonwords showed no significant differences in Turkish phonotactic frequency ($M = 98.3$ and $M = 147.7$ for the Dutch high-probability nonwords and Dutch low-probability nonwords, respectively), $F(1, 70) = 1.0$, $p > .10$.

the current study, the unexpected phonotactic probability effect in Turkish found for the monolingual Dutch group and the positive correlation between the lists of biphone clusters of Dutch and Turkish provide tentative support for the hypothesis of positive transfer from the native language to the second language. Experimental research among English–Lithuanian bilinguals indeed has shown that consonant clusters that were common in both languages were rated as more acceptable than clusters that were language specific but that these ratings depended on the bilinguals' proficiency in the languages (Anisfeld, Anisfeld, & Semogas, 1969). So, although language dominance may impede the acquisition of certain phoneme clusters that are specific for the second language and illegal in the first language, it is a distinct possibility that knowledge of phonotactic patterns common to both languages is transferred from the native language to the second language and thus supports verbal short-term recall in the second language (see also Ellis & Beaton, 1993).

Verbal short-term recall and vocabulary

Knowing that phonotactic probability influences verbal short-term recall, thereby increasing the capacity to sustain new verbal input, the question arises as to what this might imply for vocabulary acquisition. The regression analyses showed that, after statistically controlling for nonverbal IQ and the general ability to store sounds in memory (phonological loop capacity), phonotactic knowledge was an important predictor for both the native and second language vocabularies of the children. This conclusion is supported by experimental word learning studies with monolingual children at the preschool age that demonstrated superior learning of nonwords with high phonotactic probability compared with nonwords with low phonotactic probability (Storkel, 2001, 2003). For highly probable nonwords, fewer exposures were needed to learn the nonwords, whereas more associations with lexical-semantic representations were established. Thus, knowledge of phonotactics facilitates word learning, a support that is less available for the Turkish–Dutch children in their second language, Dutch. The final models of the regression analyses further revealed possible language-specific differences in the relative importance of phonotactic knowledge for vocabulary acquisition. Whereas for the Dutch language phonotactic knowledge was most important, also for the Turkish–Dutch children in this study, lexical–semantic knowledge was the most important predictor of Turkish vocabulary skills. These results could perhaps be explained by the lower native speaker ratings of wordlikeness of both sets of Turkish nonwords compared with the Dutch nonwords even though phonotactic probabilities were roughly equal. Another interesting idea, however, is that phonotactic knowledge support has a different impact for different languages. Although an explanation in terms of structural differences between the languages is beyond the scope of this article, it has been argued in the area of literacy development that Turkish, being an agglutinating language where suffixes constantly change phonological form as a function of vowel harmony, shows a developmental trajectory different from that of English (Durgunoğlu, 2006; Durgunoğlu & Öney, 1999) and perhaps also different from that of Dutch. Teasing apart the influence of phonotactic knowledge relative to lexical–semantic knowledge in vocabulary acquisition would be interesting for future cross-linguistic studies. Nonetheless, the current study has provided substantial evidence for the hypothesis that phonotactic knowledge support in verbal short-term recall is an important predictor of vocabulary in young monolingual and bilingual children in their native language as well as their second language.

Limitations and recommendations

To have highly comparable measurement instruments for both languages, we developed our own corpora from cross-translated novels. Although Dutch is a transparent language (De Jong & Van der Leij, 1999) and Turkish is even considered to be perfectly transparent (Durgunoğlu, 2006), and even though the panel check confirmed that the bigram frequency measures of wordlikeness were perceived in the same way by native speakers, the method did have some limitations. First, instead of orthographic information, ideally, spoken language corpora with phonological representations should have been used to construct the nonwords. Second, the native speakers' wordlikeness ratings were lower for the Turkish nonwords than for the Dutch nonwords. An explanation might be that we used word forms and not lemmata to count bigram frequencies because Turkish is an agglutinating language and therefore lemma counts would imply a substantial loss of phonological information. Another possibility is that the monosyllabic nonwords might have sounded less wordlike because monosyllabic words are rare in Turkish. Further improvement of the instrument could make it possible to distinguish even more precisely between recall for nonwords with high phonotactic probability and recall for nonwords with low phonotactic probability. Nonetheless, the results show that the nonwords used in the current study were sufficient to provide evidence for the phonotactic probability effect in nonword recall.

Based on the current findings, some recommendations for future studies can be made. First, earlier studies showed that the phonological loop is related not only to vocabulary skills but also to other aspects of language development in the native language (Adams & Gathercole, 2000) and in a second language (O'Brien et al., 2006). Therefore, it would be interesting to study the role of phonotactic knowledge support in other domains of language acquisition such as syntactic skills. Second, longitudinal studies are needed to provide necessary insights into the development of phonotactic knowledge support in the native and second languages. For bilingual children, such as the Turkish–Dutch group in the current study, an important question is whether the disadvantages in their second language phonotactic knowledge support are reduced once they are exposed to a rich second language environment such as the school. Furthermore, although the current study highlighted the importance of studying minority groups in experimental designs, the Turkish–Dutch group is not a balanced bilingual group with equally rich linguistic environments in both languages. Therefore, it is recommended to investigate the support of phonotactic knowledge in balanced bilingual children and in native Turkish children growing up in Turkey. Also, it would be interesting to look at the language-learning opportunities of these children in both their native and second languages in future studies and to investigate the role of parents' socioeconomic status and informal education in the home environment in developing phonotactic knowledge support. Third, correlational analyses as in the current study do not rule out the possibility that growth in vocabulary increases the influence of phonotactic knowledge on verbal short-term recall instead of the reverse, as was shown, for example, by the study of Munson, Kurtz, and Windsor (2005). Previous longitudinal studies with monolingual children suggest that the relationship between the phonological loop and vocabulary development is reciprocal, with the phonological loop being especially important during the early stages of language development between the ages of 4 and 6 years. Monolingual children with persistent poor phonological loop capacities still develop normal vocabulary levels when compensated by rich exposure (Gathercole et al., 2005). It would be very interesting to study whether the phonological loop is again relevant when the children encounter difficult words in a context that provides little direct and concrete support for the meanings such as an abstract academic text. In addition, in the case of second language acquisition, it has also been suggested that with considerable familiarity with a language, vocabulary knowledge becomes more important in the acquisition of new words compared with the phonological loop (Masoura & Gathercole, 2005). Therefore, longitudinal studies, preferably with intervention, are needed to determine whether disadvantages in phonotactic knowledge support have lasting effects on vocabulary acquisition.

Appendix A

Nonword recall tasks stimuli

	Dutch		Turkish	
	Low-probability	High-probability	Low-probability	High-probability
Block 1				
1	Jimf	Zwag	Tüj	Tım
2	Dwup	Grops	Çupk	Raşt
3	Pjoef	Zils	Föçr	Şirp
4	Fosk	Brof	Böv	Lunç
5	Pifp	Traa	Oşp	Feğ
6	Faup	Gleg	Goçk	Lıms

Appendix A (*continued*)

	Dutch		Turkish	
	Low-probability	High-probability	Low-probability	High-probability
Block 2				
1	Pjosr Fnup	Grigt Zwop	Fögl Büj	Rım Vey
2	Fuup Pjif	Spraam Kwig	Kzıt Guc	Prül Lıns
3	Vub Puif	Zifs Bropt	Glüp Nöj	Tırt Lec
4	Fjaip Dzub	Greel Knit	Pöc Gubt	Kınt Tişt
5	Fip Posf	Knog Glin	Vıp Löç	Şim Lırp
6	Pgup Dwuuf	Ziks Glof	Löf Moh	Zış Tul
Block 3				
1	Mwup Fjif Njos	Brop Sning Knilk	Vüğ Ibl Höjp	Kışt Çils Lırk
2	Ims Fwup Pjai	Zilg Brong Tris	Ibk Plöv Zühp	Nılk Rınç Külf
3	Bnup Osf Fjeum	Snins Glirg Ceng	Pröç Küg Voh	Lürt Dıy Lın
4	Fwut Gjuip fimk	Fling Brops Zwis	Vüp Zöm Jiv	Kım Diy Lüsk
5	Djai Pwut Fibs	Vlop Snilg Kwin	Sögl Cup Pıh	Lıç Girç Nım
6	Zup Kjif Fjui	Zwit Snint Dromp	Pölg Vıvl Büsp	Kürş Muy Zın

Note. Because no child exceeded Block 3, only the nonwords of the first three blocks are listed.

Appendix B

1. Turkish and Dutch corpus – Set 1: Cross-translated novels

Identical samples of text were taken from 11 novels available in official translations for both languages (5 were originally written in Dutch, 4 in Turkish, and 2 in other languages), yielding a total of 34,734 Turkish words and 47,242 Dutch words. Names, foreign words, abbreviations, and onomatopoeia were excluded from the corpora.

2. Turkish and Dutch corpus – Set 2: Cross-translated children's books

The child corpora were created using the complete texts of 42 books for children in the preschool and primary school ages available in official translations for both languages (26 Dutch origin, 6 Turkish origin, and 10 other language origin). This resulted in two equivalent written language corpora (18,107 Turkish words and 23,614 Dutch words) from which names, foreign words, abbreviations, and onomatopoeia were excluded.

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