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Research Report

Preserved Implicit Knowledge of a Forgotten Childhood Language

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ABSTRACT—***Previous research suggests that a language learned during early childhood is completely forgotten when contact to that language is severed. In contrast with these findings, we report leftover traces of early language exposure in individuals in their adult years, despite a complete absence of explicit memory for the language. Specifically, native English individuals under age 40 selectively relearned subtle Hindi or Zulu sound contrasts that they once knew. However, individuals over 40 failed to show any relearning, and young control participants with no previous exposure to Hindi or Zulu showed no learning. This research highlights the lasting impact of early language experience in shaping speech perception, and the value of exposing children to foreign languages even if such exposure does not continue into adulthood.***

Exposure to language early in life is critical in order to achieve native-like linguistic competence (e.g., Flege, Munro, & MacKay, 1995; Oyama, 1976). However, recent studies suggest that it is possible to forget an early-acquired language if contact with that language is completely severed, for example, when a child is adopted abroad by a family that speaks another language (Insurin, 2000; Nicoladis & Grabois, 2002; Pallier et al., 2003; Ventureyra, Pallier, & Yoo, 2004). In contrast, our study shows that early but time-limited exposure to a language has a long-lasting impact on a person's ability to relearn that language, even after complete separation from the language. That is, even when a person can no longer speak or recognize a word of a language learned in childhood, leftover traces are manifest as an improved ability to relearn the phonology of the language in adulthood.

In our investigation, we focused on listeners' ability to discriminate phonemes from each other. All languages are composed of an inventory of phonemes, but different languages include non-overlapping sets of phonemes, sometimes causing the speakers of one language to have difficulty distinguishing between phonemes of another language (Best, 1995; Iverson et al., 2003). A well-known example is that of adult Japanese speakers who have difficulty distinguishing between the phonemes /l/ and /r/. Indeed, Japanese listeners typically perform near chance on an AX task in which they are asked to decide whether two phonemes played one after the other are the same (e.g., /l/-/l/ or /r/-/r/) or different (e.g., /l/-/r/ or /r/-/l/). Although their performance improves after extensive training, it remains far below that of speakers of a language containing the /l/-/r/ contrast (Bradlow, Pisoni, Yamada, & Tohkura, 1997).

Constraints on learning nonnative phoneme contrasts raise a question with regard to forgotten languages: Would a person with early but brief exposure to a language show an advantage in learning phoneme contrasts as an adult, compared to someone with no relevant language history? Because savings in relearning is traditionally considered one of the most sensitive measures of memory (Ebbinghaus, 1885/1964; Nelson, 1978), it potentially provides a better test of preserved knowledge than the techniques used in previous studies. If participants in our study show a selective advantage in relearning the phonemes to which they were exposed in their childhood, it would demonstrate that this early language exposure was more deeply engraved in their memory than it appears and that the lost language was, in fact, never entirely forgotten.

Here, we focused on seven native English speakers living in the United Kingdom who were exposed to either Hindi or Zulu as children due to their parents' work abroad. A key feature of Hindi and Zulu phonologies is that both languages contain phoneme contrasts that are difficult to distinguish for native English speakers, as measured by an AX task (Best, McRoberts, & Goodell, 2001; Tees & Werker, 1984). Specifically, Hindi includes two consonant contrasts that differ in place of articulation: one dental versus retroflex voiceless consonant contrast (/t/ vs. /ʈ/, sounding like two tokens of /t/ to English listeners), and one dental versus retroflex voiced consonant contrast (/d/ vs. /ɖ/, sounding like two tokens of /d/). Likewise, Zulu includes one consonant contrast that differs in airstream mechanism: a

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TABLE 1
Details of Early Language Experience for Participants With Zulu or Hindi Backgrounds

Participant	Gender	Age at exposure (years)	Years of exposure	Age at test (years)	Vocabulary score (out of 10)
	Zulu background				
Z.D.M.: was taught Zulu in primary school, but spoke predominantly English; "very poor" Zulu ability	Male	4	4	20	3
Z.P.L.: was cared for by Zulu nanny, who sang and talked to her in Zulu; heard some Zulu at home; spoke "very largely" English, with just "odd bits of Zulu"	Female	0	7	35	3
Z.R.R.: heard Zulu spoken by caretaker and family daily; was almost fluent in Zulu	Male	3	10	47	4
	Hindi background				
H.N.F.: heard Hindi spoken by family and nanny; achieved fluency of native 4-year-old Hindi	Male	0	4	34	5
H.R.S.: was fully fluent in Hindi	Male	0	7	50	4
H.S.L.: had Hindustani housekeepers and spoke to them solely in Hindi	Female	0	5	64	4
H.S.S.: brother of H.R.S.; was fully fluent in Hindi	Male	0	5	45	3

plosive versus implosive voiced bilabial stop (/b/ vs. /ɓ/, sounding like two tokens of /b/). The question is whether the participants with a Hindi or Zulu background will selectively learn to perceive the contrasts they were exposed to and will do so more quickly than control participants.

METHOD

Participants

We tested 4 native English speakers living in the United Kingdom who were exposed to Hindi in their childhood and 3 native English speakers living in the United Kingdom who were exposed to Zulu in their childhood. These individuals learned the language as children (to varying extents), but had no remaining knowledge of the language at the time of testing (see biographical details in Table 1). In addition, we tested 4 monolingual native English speakers in their 20s who were not exposed to Hindi or Zulu in their childhood.

Background Vocabulary Test

For the vocabulary test, participants listened to the recording of 10 everyday words from their background language (produced by a native speaker) along with 10 written English words corresponding to their translation. The words were *cat*, *dog*, *father*, *foot*, *hand*, *milk*, *mother*, *no*, *stop*, and *yes*. After each spoken word, participants had to point to 1 of the 10 written words. Pointing to the same word more than once was permissible. Overall performance of the participants with a Zulu or Hindi background was 3.7 (range 3–5; see Table 1). To estimate chance level, we performed the vocabulary test with six monolingual English control participants in their 20s, who completed the task with both Hindi and Zulu stimuli. The controls performed similarly to the background participants, with an average score of 4.3 (range 3–6) on the Hindi test and 3.5 (range 2–7) on the Zulu test. The fact that participants with Zulu or Hindi backgrounds performed no better than monolingual English participants highlights the extent of their language loss. Note that the reason why the scores across all groups were relatively high is that a few of the Hindi and Zulu words shared some phonological similarity with their English counterparts (e.g., the Hindi and Zulu words for *mother* are *ma* and *oomama*, respectively).

Materials and Procedure

The Hindi and Zulu stimuli were produced by native speakers. The stimuli consisted of consonant-vowel-consonant syllables. Their initial consonant was one of the test phonemes, while their rhyme varied. For the Zulu syllables, we used 18 different rhymes, combining the nuclei /a/, /i/, and /o/ and the codas /l/, /k/, /n/, /m/, /z/, and /s/. For the Hindi syllables, we used 4 different rhymes: /al/, /ul/, /ak/, and /ut/. All Zulu syllables were pronounced four times by 4 native Zulu speakers; all Hindi syllables were pronounced four times by 8 native Hindi speakers. The quality of the Zulu recordings was rated by 3 native Zulu speakers, and the quality of the Hindi recordings was rated by 3 native Hindi speakers. For this rating task, the native speakers had to decide which of two phonemes started the test syllable (e.g., /t/ or /ʈ/) and judge the goodness of the phoneme on a scale from 1 to 8, with the two contrasted phonemes as the endpoints. We kept only recordings that were correctly identified by all native raters and rated as good exemplars by at least two of the three raters; that is, exemplars rated 1 to 2 (or 7 to 8) on the scale. Based on this criterion, 1,443 Zulu syllables and 376 Hindi syllables were kept.

The syllables were organized into 56 Hindi pairs and 56 Zulu pairs. In half the pairs for each language, the two syllables started with the same phoneme; in the other half, they started with the critical contrastive phonemes. The "same" pairs contained phonologically identical onsets from different acoustic renditions. For each test session, 112 pairs were pseudo-randomly assembled from the entire set of syllables, such that there was an equal number of Hindi and Zulu pairs and an equal number of "same" and "different" pairs. Participants were instructed to focus on the first sound of the syllables when deciding whether the two syllables started with the same or different phonemes. They were given feedback after each response (correct vs. incorrect). The 112 trials constituted 1 session of the experiment, which lasted approximately 10 min. All participants did 30 sessions, approximately 1 per day.

Four of the background participants (Z.D.M., Z.P.L., H.S.L., and H.R.S.) completed an AX task in which the two syllables were free to vary in speaker and rhyme (e.g., /baz/, pronounced by one Zulu speaker, vs. /ɓom/, pronounced by another Zulu speaker), and in which both Hindi contrasts were included (Set 1). The other participants (Z.R.R., Z.N.F., and H.S.S.) completed an AX task in which speakers and rhymes were always matched within a pair (e.g., /baz/ vs. /ɓaz/, both pronounced by the same Zulu speaker), and in which, for the Hindi contrasts, only the voiced contrast was included (Set 2). Two of the control participants completed the AX task with stimuli from Set 1, and 2 of the control participants completed the task with stimuli from Set 2 (the data of the 4 control participants are collapsed in Fig. 1). Three native speakers of Hindi and three native speakers of Zulu, tested to confirm the nativeness of our contrasts, achieved high discrimination scores on their respective contrasts after two or three AX sessions—Zulu: 91% (Set 1: 89%; Set 2: 93%); Hindi: 83% (Set 1: 79%; Set 2: 86%). Their performance on the nonnative contrasts was near chance.[1]

The experiment was run using the DMDX software (Forster & Forster, 2003) installed on a laptop loaned to each participant, who completed the sessions at home or at work. Stimuli were played over good-quality headphones at approximately 70 dB sound-pressure level. Before the first session, participants were given practice on English and a relatively easy Mandarin contrasts. The two syllables in the AX task were separated by 500 ms. Participants pressed the right shift key to indicate "same," or the left shift key to indicate "different." There were two short breaks during each session. For a demonstration of the task with stimuli from Set 2, see http://language.psy.bris.ac.uk/languagestudy/zuluhindexperiment/.

[1]We introduced the Set 2 stimuli after the first two Hindi-background participants failed to show any learning. We were concerned that the Hindi stimuli in Set 1 were too difficult and did not give participants sufficient practice on each of the Hindi contrasts.

RESULTS

To assess learning in the course of the experiment, sessions 1 to 15 were aggregated into an *early* condition, and sessions 16 to 30 were aggregated into a *late* condition. For the control participants, a mixed-effect model (Baayen, Davidson, & Bates, 2008) was run on their AX performance, with participants and stimuli as random factors, and sets (Set 1 vs. Set 2), language (Zulu contrasts vs. Hindi contrasts), and time (early sessions vs. late sessions) as fixed factors. Although performance was lower on Set 1 than Set 2 (51% vs. 66%, respectively), $F(1, 13432) = 13.68$, $p < .001$, there was no sign of learning for either set, $F(1, 13432) < 1$, and no two-way or three-way interactions between sets, language, and time, all Fs < 1 (see Fig. 1a). The same pattern of results was obtained when the results of the control participants were analyzed individually, with stimuli as the only random factor. Thus, both sets of stimuli provide an opportunity to assess relearning in the participants with Zulu and Hindi backgrounds.

The statistical outcomes of mixed-effect models for each participant with a Hindi or Zulu background are reported in Figures 1b and 1c. As is clear from Figures 1b and 1c, 2 individuals under the age of 40 with a Zulu background (Z.D.M. and Z.P.L.), and the 1 individual under the age of 40 with a Hindi background (H.N.F.), showed dramatic and selective improvement for the contrasts in their respective "forgotten" language. By the end of 30 sessions, their performance for the forgotten phonemes approached native performance (average of last 5 sessions: Z.D.M. = 86%; Z.P.L. = 83%; H.N.F. = 73%). In contrast, performance on the other phonemes showed little or no improvement (average of last 5 sessions: Z.D.M. = 55%; Z.P.L. = 51%; H.N.F. = 56%). At the same time, the Zulu-background individual over the age of 40 (Z.R.R.), and the 3 Hindi-background individuals over the age of 40 (H.S.L., H.R.S., and H.S.S.) showed no more improvement than did the control group.

DISCUSSION

We identified 7 native English speakers who learned Hindi or Zulu in childhood but who were completely isolated from the language in adulthood. Although these individuals showed no preserved knowledge of their childhood language on initial testing, after practice, a subset of them (participants under the age of 40) regained sensitivity to a phoneme contrast from their childhood language. By contrast, when the phoneme contrast was unknown in childhood, no or minimal learning was observed after extensive practice for both young and old participants. Accordingly, the current findings provide clear evidence of preserved implicit knowledge of a forgotten childhood language.

One tempting conclusion is that the age of the participants played a key role in constraining relearning. Specifically, the implicit knowledge of Hindi or Zulu for the older individuals may have been lost over the course of 40 or more years of disuse.

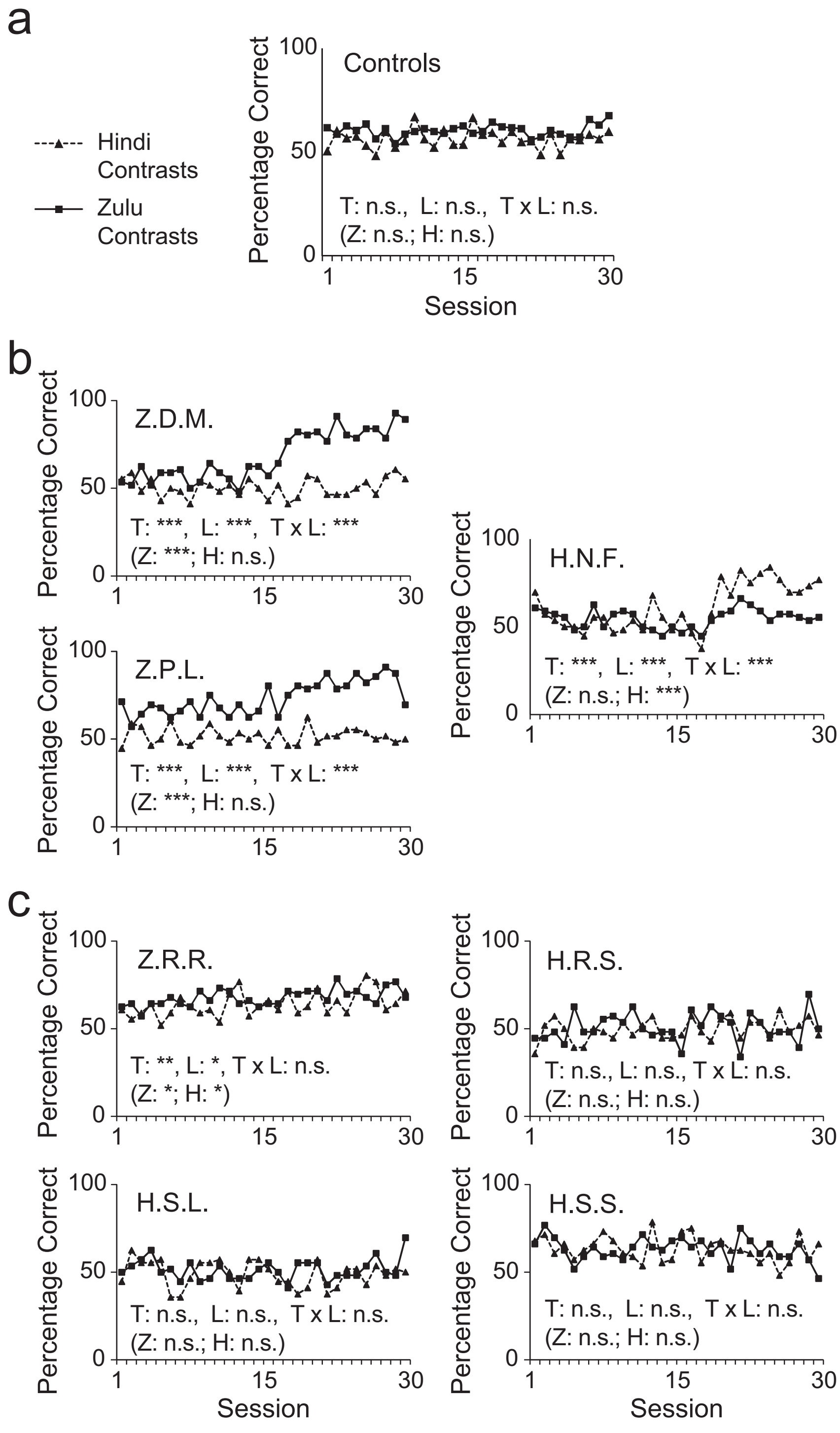

Fig. 1. Percentage of correct discrimination of the Hindi contrasts and Zulu contrasts over 30 sessions. The figure shows (a) the average performance of the 4 control native-English speakers, (b) the performance of the 3 Zulu and Hindi individuals under 40 years of age (2 with Zulu background: Z.D.M. and Z.P.L.; 1 with Hindi background: H.N.F.), and (c) the performance of the 4 Zulu and Hindi individuals over 40 years of age (1 with Zulu background: Z.R.R.; 3 with Hindi background: H.S.L., H.R.S., H.S.S.). Significance levels for statistical tests (n.s.: $p > .10$; $^{*}p \leq .05$; $^{**}p < .01$; $^{***}p < .001$) are shown in each graph. For the control group, results are collapsed across the 4 participants. Significance levels are reported individually for each participant with a Hindi or Zulu background. Results are shown for the main effect of time for the Hindi and Zulu contrasts combined (T; first 15 sessions vs. last 15 sessions), the main effect of language (L; Hindi contrasts vs. Zulu contrasts), the interaction between time and language (T × L; i.e., differential learning), the effect of time for the Zulu contrasts (Z), and the effect of time for the Hindi contrasts (H).

However, given the small sample size and the variability of the participants' exposure to the language in childhood, the role of age in modulating task performance remains, for the moment, speculative.

Perhaps the most striking aspect of the current finding is that the implicit knowledge of the forgotten language emerged only after 15 to 20 sessions. The time it took for the learning to manifest itself could explain why previous studies (Insurin, 2000; Nicoladis & Grabois, 2002; Pallier et al., 2003; Ventureyra et al., 2004) failed to show any preserved knowledge in comparable conditions. For example, Pallier et al. (2003) showed that Korean children adopted between the ages of 3 and 8 to French-speaking families were unable to distinguish spoken Korean from other non-French languages when tested in their 20s and 30s; fMRI data showed a similar pattern. Furthermore, employing a task similar to ours, Ventureyra et al. (2004) found that Korean children adopted between the ages of 3 and 9 to French-speaking families performed no differently than native French speakers on an AX task that tested discrimination of aspirated, plain, and tense stop consonants in Korean. It is only by employing a more sensitive behavioral measure, namely relearning, that we were able to reveal preserved knowledge.

Note that neither Pallier et al. (2003) nor Ventureyra et al. (2004) reported evidence for preserved knowledge on initial testing; likewise, we found no evidence on initial testing. This contrasts with other studies that have reported a robust preservation of early acquired language skills even at initial testing. For example, Tees and Werker (1984) presented native English speakers with Hindi syllables in an AX task that tested their perception of unvoiced retroflex and dental stops (one of the contrasts in the present study). The participants were studying Hindi as a second language at the university, and a subset of them ($n = 10$) reported having been exposed to Hindi for the first 1 or 2 years of life, but subsequently having little contact with Hindi. These participants performed as well as native Hindi speakers on their first test session. Similarly, Oh, Jun, Knightly, and Au (2003) tested the ability of native English speakers to perceive the difference between aspirated, plain, and tense denti-alveolar stop consonants in Korean. Participants who were exposed to Korean early in life, but who had little contact with the language in adulthood, showed better discrimination scores than individuals with no early exposure after a single test session. Similarly, production of Spanish was found to be less accented in adult native English speakers with childhood exposure to Spanish than in a control group after a single test session (Au, Knightly, Jun, & Oh, 2002; also see Au, Oh, Knightly, Jun, & Romo, 2008).

What is to be made of these contrasting results, with some studies reporting a complete loss of a childhood language on initial assessment, and others reporting preserved knowledge? Perhaps the key difference is that many of the participants in the latter studies maintained some, albeit minimal, contact with their early-acquired language throughout life. By contrast, in the studies that report no evidence of preserved knowledge on initial assessment, the participants had been completely isolated from their childhood language. Accordingly, it appears that some minimal contact with the early language throughout life helps guard against language loss. Our results indicate that, even when exposure to the childhood language is completely blocked, implicit knowledge can still be preserved.

One outstanding question is the locus of the preserved knowledge. Our findings are compatible with an account of the preserved knowledge being either phonemic (e.g., /t/ vs. /ʈ/) or subphonemic (e.g., dental vs. retroflex). Therefore, it remains to be determined whether the relearning observed in the present study generalizes to phonemes containing the critical phonetic feature contrast, even if the phonemes themselves are not part of the phonemic inventory of the background language.

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