Research Report

Background

Exposure to language early in life is critical in order to achieve native-like linguistic competence (e.g., Flege, Munro, & MacKay, 1995; Oyama, 1976). Perhaps the most striking illustration is that immigrants fluent in their second language (L2) often show deficits in the command of L2's phonology even after years of use. Indeed, L2 may show signs of an accent if it is acquired after the age of four (Flege et al., 1995). Similar deficits have been noted for L2 speech perception (Pallier, Bosch, & Sebastián Gallés, 1997).

However, a number of recent studies suggest that it is possible to forget an early-acquired language if contact with that language is completely severed (Insurin, 2000; Nicoladis & Grabois, 2002; Pallier, Dehaene, Poline, LeBihan, Argenti, Dupoux, & Mehler, 2003; Ventureyra, Pallier, & Yoo, 2004). 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 twenties and thirties; fMRI data showed a similar pattern. Furthermore, 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 a perceptual task that tested their discrimination of aspirated, plain and tense Korean stop consonants. In all these studies, the early acquired language appears to be completely lost.

These findings contrast with other studies that report preserved knowledge of a childhood language after many years of disuse. For example, Werker and Tees (1984) tested native English speakers on their ability to distinguish between two Hindi phonemes (specifically, 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 (10) reported having been exposed to Hindi for the first one or two years of life, but having little contact with Hindi subsequently. Despite the prolonged separation from Hindi, they performed as well as native Hindi speakers in distinguishing the phonemes. 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 Korean stop consonants. 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. 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 (Au, Knightly, Jun, & Oh, 2002; also see Au, Oh, Knightly, Jun, & Romo, 2008).

The conflicting conclusions of these studies could be due to the different populations tested and/or the conditions under which knowledge was assessed. For example, the participants in the Pallier et al. (2002) and Ventureyra et al. (2004) studies were completely cut off from their early acquired language after adoption, whereas the individuals in the later studies were never fully isolated from their childhood language

later in life. Accordingly, the contrasting results may indicate that early exposure to a childhood language has lasting consequences as long as some minimal contact with the language is maintained later in life. In addition, knowledge of the childhood language was assessed without any re-training in the Pallier et al. and the Ventureyra et al. (2004) study, whereas it followed explicit re-training in the latter studies. That is, in the later studies, participants were recruited from classes in which they were studying their childhood language. The raises an interesting possibility; namely, that preserved knowledge is only manifest following some re-training.

Objectives

The main objective of the current project was to assess whether adult speakers of English who were completely cut off from their childhood language would show any preserved knowledge in the context of a retraining study. We took advantage of the fact that 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, Kuhl, Akahane-Yamada, Diesch, Tohkura, Kettermann, & Siebert, 2003). A well-known example is that of adult Japanese speakers who have difficulty distinguishing between the phonemes /l/ and /r/. In the current proposal, we considered whether difficult to perceive phonemes (for English speakers) are more quickly learned by persons exposed to these phonemes as a child, but not subsequently. If so, it would reflect preserved implicit knowledge of the phonology of their “lost” childhood language.

In the original proposal, we had planned to test English speakers living in the UK who were exposed to Mandarin Chinese or Hindi under one of two conditions: (1) individuals who were adopted between the ages of one and two by English-speaking parents living in the UK and (2) individuals born of British parents who spent between one and ten years abroad during the participants' infancy or early childhood (a population that we called "temporary expatriates"). We had planned to focus on Hindi and Mandarin Chinese phoneme contrasts because we anticipated that we could identify persons with the relevant language histories (given the prevalence of Chinese adoption and the historical links between India and the UK), and based on the assumption that both languages included phoneme contrasts that are difficult to perceive by native English speakers.

However, we had to modify the design of our studies after some of these assumptions turned out to be incorrect. Most importantly, our plan to test adults in the UK adopted from China and India was unfeasible. Foreign adoption is common in North America and many European countries, but there is little history of it in the UK. Accordingly, it was not possible to identify adoptees in the UK with the relevant histories. A second (more minor) problem was that our plan to test relearning of a phonological contrast in Mandarin was not possible given that our control English participants performed well on discriminating all Mandarin phoneme contrasts (they were near ceiling from the start). Therefore, there was no opportunity to compare the learning rates of control participants and persons with Mandarin backgrounds.

In response to these difficulties, we introduced a number of changes. First, the studies carried out in the UK focused on temporary expatriates. Here, we were able to identify a number of persons with relevant linguistic histories, as described below. Second, we dropped the Mandarin phoneme contrast condition, and introduced alternatives contrasts. In the main study, we tested temporary expatriates who lived in South Africa as children on a Zulu consonant contrast that differs in airstream mechanism (/b/ vs. /≡/, sounding like two tokens of /b/ to English ears), as well as temporary expatriates who lived in Delhi as children on their ability to relearn two pairs of Hindi contrasts that differ in place of articulation (/t/ vs. / /, sounding like two tokens of /t/ and /d/ vs. /ǀ/, sounding like two tokens of /d/ to English ears). In a second experiment, we tested temporary expatriates who lived in China as children on their ability to relearn a Mandarin tone contrast (tones 2 and 3, which define minimal pairs in Mandarin but that are hard to distinglish in English), as well as temporary expatriates from Delhi on their ability to relearn Hindi contrasts. These participants were recruited through advertisements in the mainstream media, internet groups, radio, and a website: http://language.psy.bris.ac.uk/languagestudy/

Third, we developed a Web version of our experiment, which allowed us to test persons living in the USA who were adopted from Korea and China. Foreign adoption from Korea and China is relatively common in the USA (although Chinese adoption only started in the early 1990s, so it is relatively difficult to test adults over 18). On the Web experiment, we trained participants to relearn a Korean contrast that differs in voice onset time (the phonemes /t/ and /t^h/ that sound like two tokens of the phoneme /t/ to English ears), as well as the Mandarin tones 2 vs. 3 contrast from Experiment 2.

To summarise, we ran three Experiments. First, we assessed relearning of Hindi and Zulu contrasts in temporary expatriates living in the UK. The main question was whether these persons would show any preserved knowledge of their childhood language, as reflected by the selective relearning of the phonemes they knew as children. As described below, some of these persons did show striking evidence of preserved implicit knowledge. Second, we assessed relearning of Hindi phoneme contrasts and Mandarin tones in temporary expatriates living in the UK. Again, the question was whether these participants showed any selective relearning of the contrasts that they knew as children. This study failed to show any relearning, as described below. Third, we assessed relearning of Mandarin tones and Korean contrasts in adoptees living in the USA. This study also failed to provide evidence of any preserved knowledge, as described below. In all studies, we considered the impact of the persons' specific history in modulating relearning effects. Specifically, we considered the extent to which the number of years the person was exposed to the childhood language and the number of years separating exposure and testing impacted on relearning.

Together, these studies provide compelling evidence that phonological knowledge of a forgotten childhood language can be preserved under some conditions, even when the person is completely isolated from their childhood language as an adult, and even when they show no explicit knowledge of this language prior to retraining.

Stimuli and Methods

Experiment 1: The Hindi and Zulu stimuli were produced by native speakers. The stimuli consisted of consonant-vowel-consonant syllables. The initial onset consonant was the target phoneme; the rhymes varied from syllable to syllable. For the Zulu syllables, the onset contrast varied in airstream mechanism: a plosive vs. implosive voiced bilabial stops (/b/ vs. /≡/, sounding like two tokens of /b/). 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 included two onset contrasts that varied in place of articulation: a dental vs. retroflex voiceless consonants (/t/ vs. / /, sounding like two tokens of /t/), and a dental vs. retroflex voiced consonants (/d/ vs. /̪/, sounding like two tokens of /d/). We used 4 different rhymes: /al/, /ul/, /ak/, and /ut/. All Zulu and Hindi syllables were pronounced four times by 4 native Zulu speakers and 8 native Hindi speakers, respectively. The quality of the recordings was rated by three native speakers of each language. We only kept recordings that were correctly identified by all native raters, and rated as good exemplars by at least two of the three raters (1-2 or 7-8 on a 1-to-8 scale between the two endpoint phonemes). Based on this criterion, 1443 Zulu syllables and 376 Hindi syllables were kept.

In order to measure relearning, we employed an AX task that has been used in previous studies to assess the perception of non-native speech sounds, e.g., discrimination of the /r/-/l/ contrast by Japanese speakers (e.g., Bradlow et al., 1997) and of Mandarin tones by English speakers (e.g., Wang et al., 1999). Participants were presented with two syllables in turn (with ~500 ms ISI) and were instructed to decide whether the syllables shared the same onset or not. Feedback was given on each trial. The syllables from the two languages were randomly intermixed, and 112 trials were completed per session, with 30 sessions completed in total over approximately a month (~ one a day).

Experiment 2: In addition to the Hindi stimuli, we used a set of Mandarin syllables from Wang, Spence, Jongman, and Sereno (1999). Four different speakers each produced 45 syllables with two different tones (tones 2 and 3), for a total of 360 recordings. Syllables were paired in the AX task so that their tones matched on half of the trials and mismatched on the other half. Relearning was assessed using the AX task. The Hindi and the Mandarin trials were blocked so that participants knew whether to focus on a phoneme or a tone contrast. Again, 112 trials were completed per session, with 30 sessions completed in total. Both Experiments 1 and 2 were carried out on a laptop provided by the experimenter, and participants were provided with high quality headphones. Experiments were carried out at the participants' home.

Experiment 3: We assessed learning of the above Mandarin tones as well as a Korean stop consonant contrast that varied on voice onset time (cf. Ventureyra, Pallier, & Yoo, 2004). The test stimuli consisted of consonant-vowel-consonant syllables, with the critical contrast in onset position (/t/ vs. /$t^{h/}$), followed by one of four vowels (/oh/, /ih/, /uh/ and /a/), and seven codas (/k/, /n/, /t/, /l/, /m/, /p/, and /ng/). Two male and two female native Korean speakers produced 4 tokens of each syllable for a total of 896

recordings (2 onsets x 4 vowels x 7 codas x 4 speakers x 4 tokens). As with the Hindi stimuli, the quality of the recordings was rated by three native speakers, and we only kept recordings that were correctly identified by all native raters and rated as good exemplars by at least two of the three raters.

The same general AX procedure was used, with Mandarin and Korean stimuli blocked. But in this case, the experiment was run via our webpage on the Internet, and English speakers living in the USA who were adopted from China or Korea were tested. Again, 112 trials were completed per session, with 30 sessions completed in total. Participants carried out the study in their home over the Internet (http://language.psy.bris.ac.uk/languagestudy/experiment/).

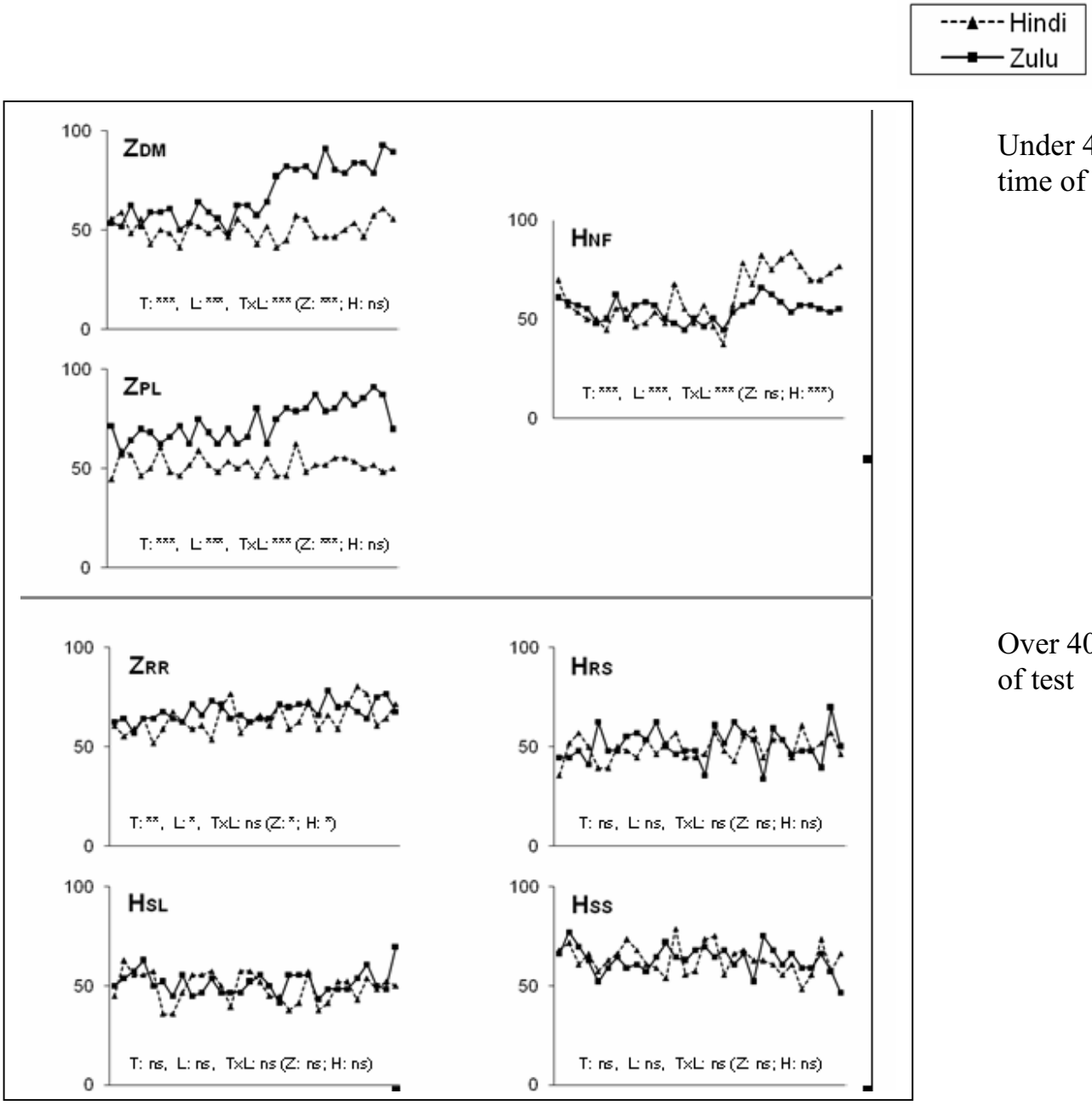
In all experiments, we asked control participants with no previous exposure to any of these languages to complete the 30 training trials. Preserved implicit knowledge of the forgotten childhood language could thus be revealed in two ways. First, a person exposed to a foreign childhood language might show selective learning of syllables from their forgotten language (e.g., a person exposed to Zulu as a child learns to distinguish Zulu phonemes better than the Hindi phonemes and vice versa for a person exposed to Hindi as a child). Second, a person exposed to a foreign language might show more learning for phonemes from this language compared to a control participant who was not exposed to any foreign language as a child. In all experiments, performance was measured as percent correct in responding "same" vs. "different" to the stimuli in the AX tasks over the 30 test sessions.

To easily assess the statistical significance of the learning patterns, sessions 1 to 15 were aggregated into an *early* condition and sessions 16 to 30 into a *late* condition. A mixed-effect model (Baayen, Davidson, & Bates, 2008) was run on the AX performance, with participants and stimuli as random factors, and Language (two contrasts taken from Zulu, Hindi, Korean or Mandarin contrasts), and Time (early vs. late) as fixed factors.

Results

Experiment 1: The learning curves of seven temporary expatriates exposed to Hindi or Zulu as a child are displayed in Figure 1. Participants labelled H_{NF}, H_{SL}, and H_{SS} were exposed to Hindi, and participants labelled Z_{DM}, Z_{PL}, and Z_{RR}. The details of their exposure to Hindi and Zulu as children is shown in Table 1. As can be seen from the figure, all participants performed the task at near chance levels for the first 15-20 sessions, but participants under the age of 40 at the time of test showed selective learning of their phonemes in the later training sessions. Four control participants in their 20s showed no learning (not shown in Figure 1). Statistics are summarised for each participant: T: main effect of Time (first 15 sessions vs. last 15 sessions). L: main effect of Language (Hindi contrasts vs. Zulu contrasts). TxL: interaction between Time and Language, i.e., differential learning. Z: effect of Time for the Zulu contrasts. H: effect of Time for the Hindi contrasts. ns: $p > .10$; *: $p \leq .05$; **: $p < .01$; ***: $p < .001$.

Figure 1.



Under 40 at time of test

Over 40 at time of test

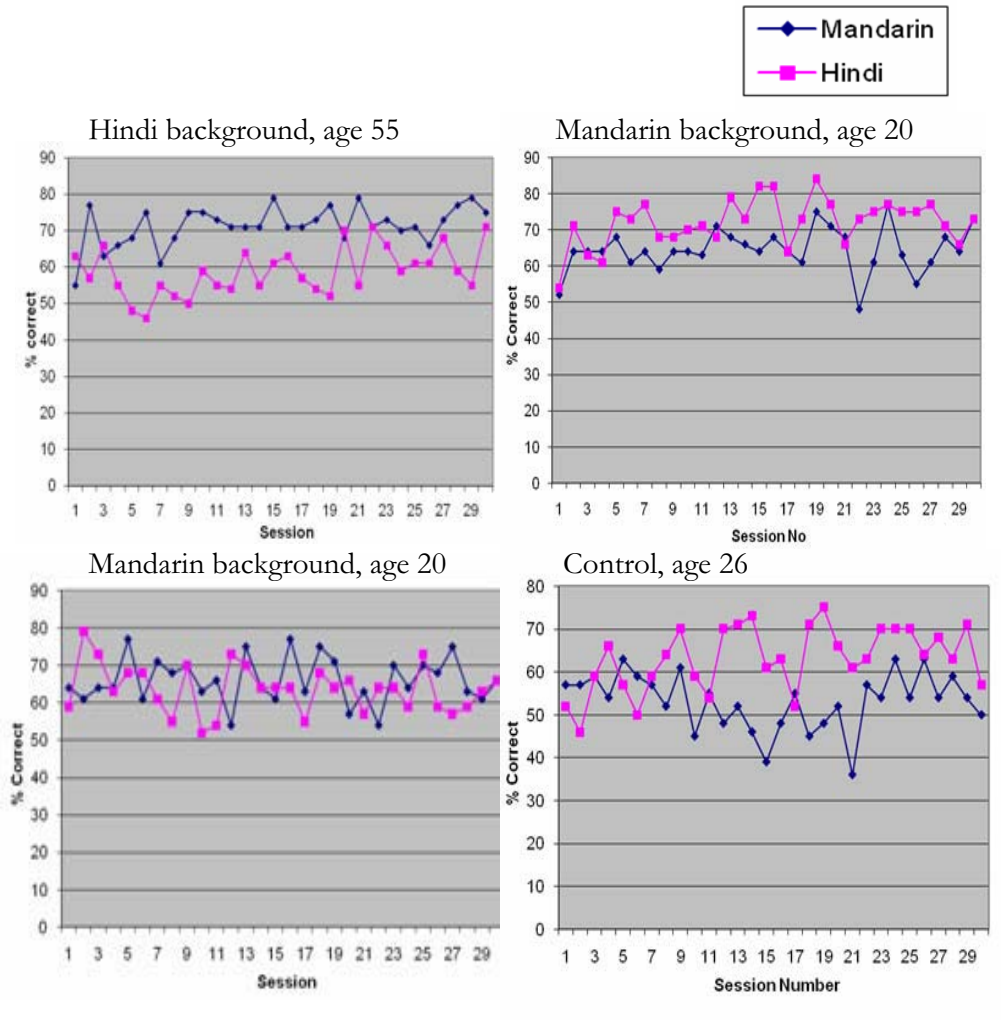
Table 1. Details of early language experience for the Zulu- and Hindi-background participants.

Participant	Age at Exposure	Years of Exposure	Age at Test	Vocabulary Score (/10)*
Zulu 1 (ZDM). Male. Was taught Zulu in primary school, but spoke predominantly English. Zulu ability was 'very poor'.	4	4	20	3
Zulu 2 (ZPL). Female. Had Zulu nanny, who sang and talked to her in Zulu. Some Zulu spoken at home. Spoke 'very largely' English, just 'odd bits of Zulu'.	0	7	35	3
Zulu 3 (ZRR). Male. Zulu was spoken by carer and family daily. Was almost fluent.	3	10	47	4
Hindi 1 (HSL). Female. Had Hindustani house keepers and spoke to them solely in Hindi.	0	5	64	4
Hindi 2 (HRS). Male. Achieved full fluency.	0	7	50	4
Hindi 3 (HSS). Male. Brother of RS. Achieved full fluency.	0	5	45	3
Hindi 4 (HNF). Male. Spoken by family and nanny. Spoke up to level of native 4-year old Hindi.	0	4	34	5

*In order to assess participants' explicit knowledge of their childhood language before training we presented them with a vocabulary test. Participants listened to the recording of 10 everyday words from their background language (produced by a native speaker) alongside 10 written English words corresponding to their translation. The words were: cat, dog, father, foot, hand, milk, mother, no, stop, yes. After each spoken word, participants had to point to one of the 10 written words. Pointing to the same word more than once was permissible. Overall performance of the background participants was 3.7/10 (range 3-5). In order to estimate chance level, six monolingual English control participants in their twenties completed the task with both Hindi and Zulu stimuli. The controls performed similarly to the background participants, with an average score of 4.3/10 (range 3-6) on the Hindi test and 3.5/10 (range 2-7) on the Zulu test. The fact that our background participants performed no better than monolingual English participants highlights the extent of their language loss. Note that the scores were relatively high because some 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).

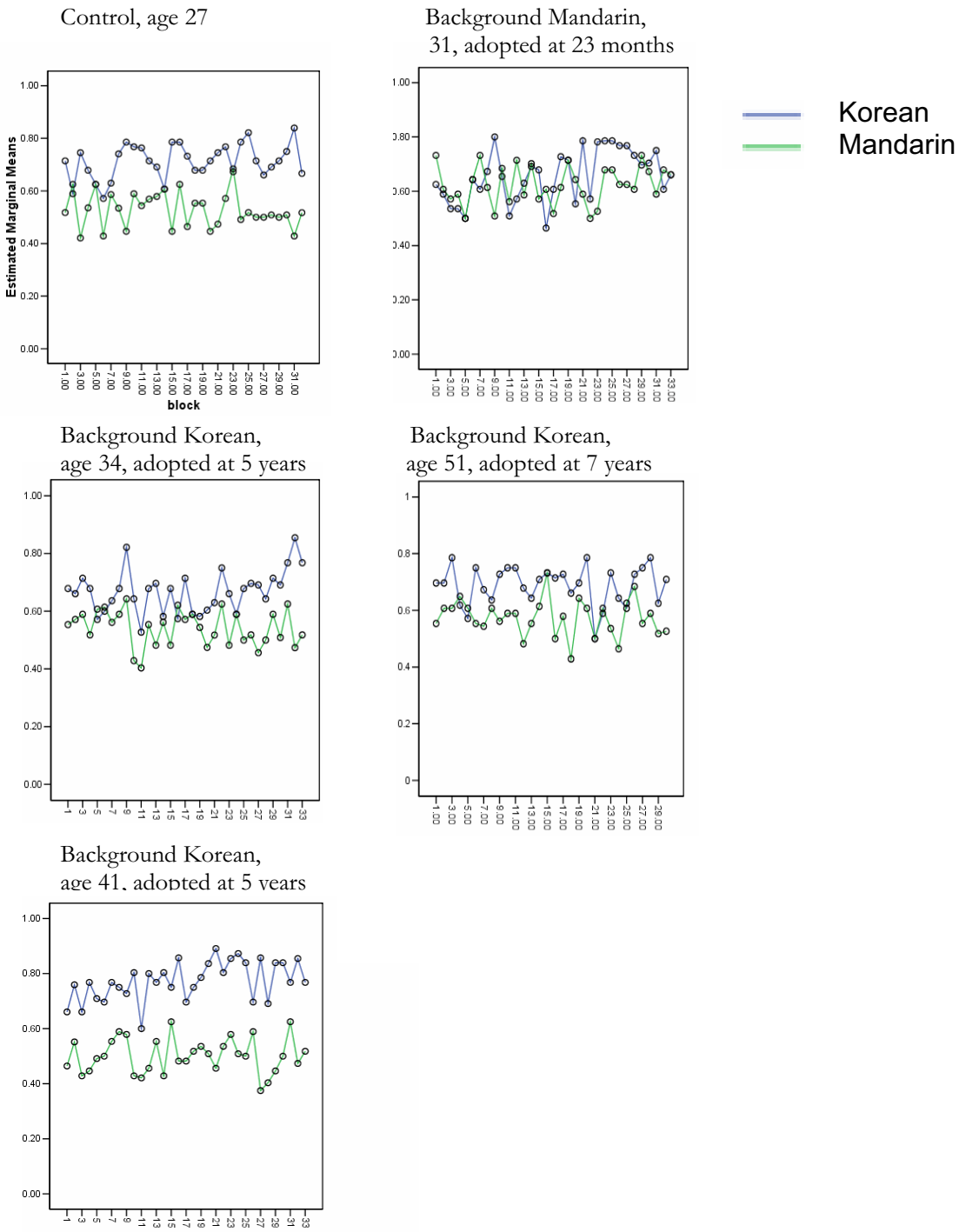
Experiment 2. Learning curves for 3 temporary expatriates exposed to Hindi or Mandarin as a child, as well as a control participant. As is clear from this figure, no participants showed any evidence of learning. The one participant with a Hindi background was 55 years of age and, based on the results of Experiment 1, it is not surprising that she failed to show any learning. By contrast, the participants with early exposure to Mandarin were young at the time of test (both aged 20) and, accordingly, it is surprising that they showed no advantage in retraining.

Figure 2.



Experiment 3. Learning curves for 4 adopted participants from China and India, along with a control participant.

Figure 3.



As is clear from Figure 3, the participant exposed to Mandarin as a child showed no evidence of preserved implicit knowledge for the two tones (as was the case in Experiment 2). One possibility is that relearning tones is simply more difficult than relearning phoneme contrasts. In the present case, however, the individual was under the age of 2 at the time of adoption, and this may not be sufficient exposure to maintain implicit knowledge for an extended period.

Also noteworthy, the participants adopted from Korea were in fact better on Korean compared to Mandarin contrasts, which might suggest some preserved implicit knowledge of Korean. However, the control participant showed the same pattern of results. There is therefore no compelling evidence that the Korean adoptees maintained any implicit knowledge of Korean phonology. On the other hand, two of these participants were over the age of 40 at time of test, and accordingly, their failure to show any preserved knowledge is consistent with the findings in Experiment 1. Yet, one Korean adoptee was under 40, and thus, we could have expected more evidence of preserved knowledge for that individual relative to the control participant. Clearly, we need to identify more adoptees before any strong conclusions can be drawn from this experiment.

Overall Summary

The key results were obtained in Experiment 1 (Bowers et al., in press), which provided evidence for preserved implicit knowledge of a childhood language. Perhaps the most striking aspect of this study was that the implicit knowledge of Hindi and Zulu language only emerged after 15 to 20 sessions. The time it took for the learning to manifest itself could explain why some previous studies (Insurin, 2000; Nicoladis & Grabois, 2002; Pallier, et al., 2003; Ventureyra et al., 2004) failed to show any preserved knowledge. It is only by employing a more sensitive behavioural measure, namely relearning, that we were able to reveal preserved knowledge.

These findings complement other studies that have reported a robust preservation of early acquired language skills (e.g., Oh, Jun, Knightly, and Au, 2003; Werker & Tees, 1984). However, as noted above, the participants in the latter studies were never completely isolated from their early languages. Accordingly, the current findings extend these results, and show that knowledge can be preserved even when all explicit knowledge of the childhood language is lost. These findings highlight the importance of early language learning – even if an early acquired language is not practiced for many years, the benefits can still be observed in terms of faster relearning.

Nevertheless, there are obviously limitations to how effective relearning can be. We failed to observe any preserved knowledge in adults over 40 and we have failed to obtain any evidence of preserved implicit knowledge of Korean phonemes and Mandarin tones, even in younger participants. Future work is required to determine whether preserved implicit knowledge can be observed in these latter conditions.

Activities

Because of the challenges in recruiting participants, we were not able to disseminate our results until the final year of the grant. In the final year of the grant, we presented this work in a talk format at Psychonomics (2008) in Chicago, and the first author presented this work to the Bilingualism Centre at Bangor University in November 2008. Some preliminary results were presented in the Department of Psychology, University of Arizona, in November 2007. While at the University of Arizona, we started planning Experiment 3, which tests English speakers adopted from Korea or China to families living in the USA.

In addition, preliminary reports were presented in the press (e.g., Bristol Evening Post, June 13, 2007) and discussed on the Radio (e.g., Star Radio 107.5, Bristol). The work was also mentioned in the ESRC SocietyToday news letter (24 September, 2007).

Outputs

Bowers, J.S., Mattys, S.L., & Gage, S.H. (in press). Preserved implicit knowledge of a forgotten childhood language. *Psychological Science.*

Impacts

None thus far.

Future Research Priorities

In future work, we plan to test more adopted participants. The development of the web version of the experiment makes it much easier to test participants remotely, and we are optimistic that we can now recruit more adoptees with relevant linguistic histories. This will allow us to better understand the conditions in which implicit knowledge is preserved. Key issues are: (1) whether it is possible to show preserved implicit knowledge of Korean phonemes and of Mandarin tones, and (2) whether is it possible to show preserved implicit knowledge when testing participants are over the age of 40.

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