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Age and amount of exposure to a foreign language during childhood: Behavioral and ERP data on the semantic comprehension of spoken English by Japanese children

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ABSTRACT

Children's foreign-language (FL) learning is a matter of much social as well as scientific debate. Previous behavioral research indicates that starting language learning late in life can lead to problems in phonological processing. Inadequate phonological capacity may impede lexical learning and semantic processing (phonological bottleneck hypothesis). Using both behavioral and neuroimaging data, here we examine the effects of age of first exposure (AOFE) and total hours of exposure (HOE) to English, on 350 Japanese primary-school children's semantic processing of spoken English. Children's English proficiency scores and N400 event-related brain potentials (ERPs) were analyzed in multiple regression analyses. The results showed (1) that later, rather than earlier, AOFE led to higher English proficiency and larger N400 amplitudes, when HOE was controlled for; and (2) that longer HOE led to higher English proficiency and larger N400 amplitudes, whether AOFE was controlled for or not. These data highlight the important role of amount of exposure in FL learning, and cast doubt on the view that starting FL learning earlier always produces better results.

1. Introduction

Language learning is an important part of human cognition, and the learning of a second language (L2) is currently receiving much social as well as scientific attention. Bilingualism is not an exception but already the norm in many countries. Even in linguistically less heterogeneous countries, the learning of a foreign language (FL) is often obligatory at secondary schools. Perhaps the most attention-grabbing issue in L2/FL research is whether age of first exposure (AOFE) to the L2/FL has any effects on the final outcome of learning and the speed of learning (AOFE is also called age of acquisition or AOA). So far, clearest advantages of early AOFE have been found in phonology. For example, immigrants who immigrated earlier in life tend to have better L2 phonological skills than do those who immigrated later (Oyama, 1976). Also, younger children seem to be superior to older children in the perception of unfamiliar FL sounds to which they have never been exposed (Tahta et al., 1981). Inability to accurately and quickly perceive linguistic sounds can become a bottleneck to the acquisition and processing of lexical items (Mayberry, 1994). This phonological bottleneck hypothesis implies that there could be AOFE effects not only on phonology but also on lexical acquisition and processing. Despite the commonly held view that AOFE effects do not extend to lexical acquisition and semantic processing (Newport et al., 2001), this implication has been supported by a number of empirical studies on deaf individuals and cochlear implant users (Connor et al., 2000; Emmorey and Corina, 1990; Mayberry and Fischer, 1989).

The possibility that poor phonological skills impede lexical acquisition and semantic processing has an important implication for FL learning. It is known that the phonological system of the mother tongue (or first language, L1) influences the perception of L2/FL sounds. For example, the distinction between /l/ and /r/ in English is notoriously difficult for native Japanese speakers to perceive (Goto, 1971). Perceptual sensitivity to certain non-native sound contrasts seems to decline rapidly during the first year of life (Kuhl, 2004). It might be the case that younger children have a

Abbreviations: FL, foreign language; L1, first language or mother tongue; L2, second language; AOFE, age of first exposure; HOE, hours of exposure.

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superior ability to learn spoken FL words compared to older children. This possibility was directly tested by a study of 30 Japanese children who had never been exposed to English (Yamada et al., 1980). In an experimental situation, they were asked to learn spoken English words, and it was found that younger children can outperform older ones in this task. Many phonological differences exist in certain pairs of languages. For example, English and Japanese differ in the syllable structure (e.g. English allows the clustering of consonants but Japanese does not), the number of vowels (English has 13 vowels but Japanese has only 5), and the inventory of consonants (as exemplified by the absence of the distinction between /l/ and /r/ in Japanese). Larger phonological differences between the L1 and the FL may lead to greater difficulties in phonological learning in the FL. Lexical acquisition and semantic processing in the auditory modality may in turn be more difficult if the FL greatly differs from the L1 phonologically and the onset of FL learning is late.

Another important factor in FL learning beside AOFE is the amount of exposure. A well-known classic study of college students majoring in an FL emphasizes the role of amount of exposure over that of AOFE (Carroll, 1967). Generally, longer exposure leads to the attainment of higher levels of FL proficiency, but the amount of exposure necessary to attain a specific level of proficiency varies greatly among different L1–FL pairs. A large-scale study of native English speakers highly motivated for FL learning (Foreign Service Institute, 1973) reports that two to three times more hours of learning are necessary to attain the same level of speaking proficiency in the most difficult languages including Japanese, compared to the easiest languages including French and Spanish. These data clearly illustrate the important role of amount of exposure particularly in some pairs of languages like the English–Japanese pair. By definition, an FL is not spoken in the community where the learner lives. It is thus a practical problem of FL learning how the learner can secure long enough exposure to the FL. This difficulty is exemplified by an estimate that 18 years of FL learning are necessary to gain the same amount of exposure obtained in 1 year of immigrants' L2 learning (Singleton, 1989). Note also that amount of exposure is critical even in L1 acquisition, where 10,000 h of exposure are estimated to be necessary for children to attain basic levels of proficiency (Clark, 2003).

Here we aim to study the effects of AOFE and amount of exposure on child FL learning utilizing both conventional behavioral data and more recent neuroimaging data. As neural indices, event-related brain potentials (ERPs) were used in this study. ERPs are online electrical measures of neural activities, obtained by time-locking scalp-recorded electroencephalograms (EEGs) to a certain event such as the presentation of linguistic stimuli (Rugg and Coles, 1995). ERPs can visualize language processing as it is occurring, and provide online data of early linguistic processes well before any conscious decision can be made. The results of offline behavioral tasks such as conventional pencil-and-paper language tests may be influenced by individual variation in conscious decision-making and test-taking strategies which are not part of the core language processes. These non-linguistic variables may have influenced the results of previous behavioral studies in favor of the learner who is competent in these variables (Muñoz, 2006). By using the ERP technique, we tried to provide online data which were not contaminated by these factors. The value of the ERP technique as a tool to visualize online language processing can be particularly large in the specific context of certain countries like Japan, where FL education has been dissatisfactory to many people in previous generations. One of the criticisms often raised is that the knowledge acquired through FL education is useless in real, speedy conversation. If FL education is tightly connected with university entrance exams which heavily rely on traditional pencil-and-paper methods of testing like in Japan, the acquisition of the ability to use the FL in a speedy manner can be ignored or at least less emphasized in education. The introduction of FL education at younger ages has been partly motivated against these backgrounds. Thus online measures like ERPs may provide valuable information as to whether FL education really enhances speedy online processing capacity necessary for real conversation.

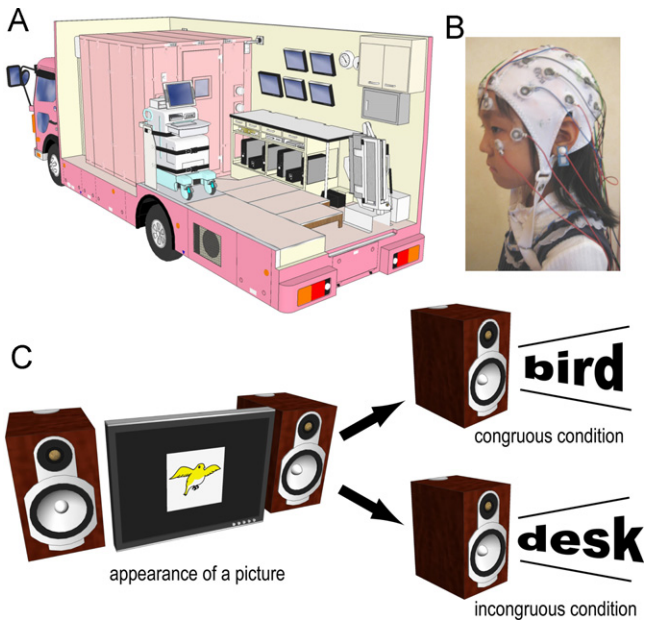

Fig. 1. Methods summary. (A) Our neuroimaging vehicle. (B) A child wearing an EEG cap. (C) Stimulus presentation. The spoken words played back from the loudspeakers were either congruous or incongruous in meaning with the preceding picture contexts.

ERPs have already been used extensively to study adults' L1 processing (Friederici, 2002; Kutas and Federmeier, 2000), children's L1 acquisition (Hahne et al., 2004; Holcomb et al., 1992), and adults' L2/FL learning (McLaughlin et al., 2004; Ojima et al., 2005; Rossi et al., 2006). The value of ERP data in L2/FL research is exemplified by a study of Japanese adults who had high English proficiency (Ojima et al., 2005). These Japanese adults scored slightly higher than native speakers of English in offline pencil-and-paper grammaticality judgments of English sentences, but their ERPs elicited by the same sentences contained only a LAN (left anterior negativity) and lacked the P600 component which was clearly present in the native speakers. As of now, very few ERP studies have focused on children's L2/FL learning (Ojima et al., 2011), and to our knowledge, no previous study has seriously addressed the effects of AOFE and amount of exposure on children's L2/FL learning.

Our neuroimaging vehicle (Fig. 1A), which we drove to seven primary schools, enabled the acquisition of a large number of data; a total of 814 ERP datasets obtained longitudinally from 350 children entered the analyses in the current study. Equipped with an EEG room, the vehicle enabled data acquisition at children's own schools. In our ERP experiment, we specifically targeted children's semantic processing of spoken words. Delayed exposure leads to limited phonological capacity in L1 acquisition, and limited phonological capacity in turn may impede rapid and efficient lexical learning and semantic processing (Mayberry, 1994). Late-onset L2 learning also leads to persistent phonological problems (Oyama, 1976), and younger children's superiority in the learning of spoken FL words in an experimental situation has been reported (Yamada et al., 1980). Thus there is a possibility that advantages of early AOFE will appear on children's processing of spoken words in the FL.