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Neurocognitive approaches to bilingualism: Asian languages

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In the last decade there has been a surge of interest in the use of neuroimaging tools such as event-related potentials (ERP) and functional magnetic resonance imaging (fMRI) to examine critical issues in the representation and processing of multiple languages in the brain. In 2001, David Green edited a special issue for *Bilingualism: Language and Cognition* on the cognitive neuroscience of bilingualism that involved studies of bilingual populations in English, German, Italian, and Japanese. According to a review by Vaid and Hull (2002), by 2001, there were at least 25 fMRI studies and 13 PET (positron emission tomography) studies of bilingual language processing in healthy individuals. This number has grown more rapidly since 2001. Many of these neuroscience studies of bilingualism have also appeared in top science journals and attracted widespread attention.

Given the prominence and interest that this line of research has generated, we present the current special issue. The focus is on Asian languages for the key reason that Asian languages have specific linguistic properties not available in commonly examined languages. These include non-alphabetic scripts/writing systems, lexical tones, flexible grammatical and syntactic structures, and unique lexical compounding characteristics. The importance and implications of these language-specific properties have been explored in other contexts (see reviews in Li, Tan, Bates and Tzeng, 2006), but have not been extensively examined in the bilingual context though there is increased interest in doing so (see Grosjean, Li, Münte and Rodriguez-Fornells, 2003 and Vaid and Hull, 2002).

As we see in this special issue, the similarities and overlaps in the linguistic properties of the bilingual's two languages play a very important role in shaping patterns of second language acquisition and processing. The language-specific properties of Asian languages, along with the large (and growing) population of Asian bilingual speakers, make it a worthwhile project to examine the neurocognitive substrates underlying bilingual language acquisition and representation for this population. It is against this background that we feel that the current issue will make a significant contribution to the rapidly growing field of the neurocognition of bilingualism.

Bialystok and Luk argue that learning to read involves the same initial step of understanding the symbolic nature of print, regardless of whether the writing system is alphabetic (e.g., English) or non-alphabetic (e.g., Chinese). In the neuroimaging literature there has been debate on whether the reading of alphabetic versus non-alphabetic symbols is subserved by distinct neural circuits. The current study indicates that although writing systems involve different visual features and different relationships between sounds and meanings (and therefore possibly different neural structures), the basic challenge to the child (monolingual or bilingual) in learning to read remains the same, at least with respect to the symbolic understanding of print.

Granted commonality in the initial stage of a language task such as reading, what conjectures can guide our approach to understanding the neural regions underpinning the acquisition and use of different second languages? One plausible hypothesis is that the acquisition and use of different languages involves a common network of brain regions. In native speakers of European languages there is good evidence about the nature of these regions (Indefrey and Levelt, 2004) and evidence too that both left-hemisphere and right-hemisphere networks are involved. The notion that different languages recruit a common system (the "convergence hypothesis", Green 2003) indicates the importance of examining how the first language (L1) influences the acquisition and processing of a second language (L2). Some differences in the processing of a language by a native speaker compared to a second language speaker can be attributed to differences in the level of proficiency associated with how speakers manage competition between their languages (Abutalebi and Green, 2007). However, other differences, whether these are long-lasting or short-term, are likely to reflect the precise properties of the first language. The notion that a first language tunes or adapts the neural networks underpinning language use is a central theme of all the neuroimaging papers in this issue.

Reviewing the behavioural, electrophysiological, and fMRI findings on reading, Perfetti, Liu, Fiez, Nelson, Bolger and Tan contrast the Chinese writing system with alphabetic writing systems. These authors propose the "system accommodation hypothesis", according to which distinct writing systems impose cognitive-perceptual constraints that the learner must accommodate during

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the acquisition process. For example, English learners of Chinese show accommodations to the high visual-spatial demands of Chinese characters by recruiting the right-hemisphere visual areas to handle the spatial analysis task for the characters, resources that are not needed in alphabetic writing. However, the accommodation process may be asymmetric, such that Chinese learners of English can rely more on assimilation than accommodation. In other words, Chinese learners can use their L1 reading strategy to handle the reading task for the L2, as revealed by bilateral occipital and occipital-temporal activation for both characters and alphabets. These findings have important implications with respect to the bilingual development of reading skills, and are consistent with the view that the neural networks of L1 can have significant impact on the cognitive and neural representation of the L2, especially when there are important distinctive properties.

The article by Zhang and Wang provides an integrated review of the neural plasticity issue in the context of phonetic learning, in both L1 and L2 acquisition. Zhang and Wang examine how early phonetic experience in L1 may lead to dedicated cognitive and neural structures that affect the processing pattern and outcome of later L1 and L2 learning. The authors focus on the effects of early experiences with one's native language on the process of second language acquisition, in particular, how phonetic processing in infancy could account for the reduced sensitivity in L2 speech discrimination and, later, lexical-grammatical acquisition. Zhang and Wang further discuss the relationships between neural plasticity, neural efficiency, neural specificity, and neural connectivity, as revealed by ERP and functional neuroimaging studies when L2 learners are trained to discriminate nonnative speech sound contrasts (e.g., Japanese speakers on the /l/–/r/ contrasts in English, and English speakers on the tonal contrasts in Mandarin).

The overall approach espoused by these authors suggests a new perspective on the infamous critical period of language learning. Rather than attributing any constraints on the acquisition of an L2 to a maturational or biological timetable, we should see the constraints on language learning as a product of the dynamic interactions between early experience, perceptual capacity, and competition to represent a later language. Language acquisition is a dynamic process shaped by cognitive, linguistic, and social factors. Such a perspective is highly compatible with findings from the computational modelling of the trajectories of lexical development in L1 and L2 (Li and Farkas, 2002; Hernandez and Li, 2007; Li, Zhao and MacWhinney, 2007).

Chen, Shu, Liu, Zhao and Li present an empirical study that draws on the ERP method to examine Chinese learners' processing of subject–verb agreement in English. In Chinese, unlike English and other Indo-European languages, grammatical morphology does not mark case, gender, or number; thus, subject–verb agreement in sentences is not required. Previous research has investigated ERP responses to morphosyntactic features in both L1 and L2, but most of this research was conducted in Indo-European languages (see e.g., Tokowicz and MacWhinney, 2005; Osterhout, McLaughlin, Pitkanen, Frenck-Mestre and Molinaro, 2006). Chen and colleagues indicate that when the relevant morphosyntactic properties are absent in L1, learners may show behaviourally similar patterns to native speakers but the neural markers of their responses to morphosyntactic violations may be very different, as revealed by ERP patterns. While a typical biphasic LAN-P600 pattern is observed with native speakers in response to agreement violations, this pattern is absent in the L2 learners. Given an L1 that does not encode grammatical morphology (Chinese), the learning of a syntactic agreement system in an L2 (English) presents a major obstacle for L2 learners. An important extension for future work would be to examine Chinese learners who acquire English in an immersion environment. In general, these results are taken to support the proposal that language-specific experiences with L1 shape the neural patterns of L2 processing, consistent with two other papers in this volume, by Perfetti, Liu, Fiez, Nelson, Bolger and Tan, and by Zhang and Wang.

Jeong, Sugiura, Sassa, Yokoyama, Horie, Sato, Taira and Kawashima contrast the activation patterns of two different native language groups (native Korean speakers and native Chinese speakers) as they listened to sentences in English (acquired around puberty) and Japanese (acquired around 20 years of age). The study was conducted as both groups were pursuing their degrees in Japan. The key data concern the different activation patterns for processing English and for processing Japanese for the two groups. By way of illustration, whereas Chinese and English use an SVO word order, Korean and Japanese use the SOV word order. Indeed Korean participants showed greater activation in processing English sentences in regions linked to syntactic processing while Chinese participants showed an increase in processing Japanese sentences in such regions. Interestingly, length of stay in Japan was associated with decreased activation in a subcortical area (left caudate) that has been linked to language control and switching (Crinion et al., 2006) but only for the Chinese speakers. Conceivably decreased activation is linked to a decrease in the requirement to switch the order of words in order to interpret the meaning of a sentence or to a decrease in implicit translation of the presented sentence into Chinese.

Acquisition of a language can be likened to the acquisition of a skill. Neural structures central to that skill may alter in response to functional demand. Green, Crinion and Price first review evidence showing specific effects of skill acquisition on brain structures. A key feature of acquiring a language is learning the vocabulary. The authors review the behavioural and functional studies on second language vocabulary acquisition, and then report ongoing work on structural brain changes. They show that a specific region of the parietal cortex, well-positioned to connect the sounds and meanings of words, increases in grey matter density as a function of vocabulary knowledge within monolingual English speakers. The same region shows increased density for bilingual as compared to monolingual English speakers. After reviewing functional studies on tone processing, Green and colleagues report data showing that regional change in the same parietal area is also true of bilinguals who speak English and Chinese. However, relative to European bilinguals, Chinese speakers show increased grey matter density in a number of other left-hemisphere and right-hemisphere regions that may reflect the use of tone to signal lexical differences or to maintain speech representations. All current reported studies are cross-sectional and need to be complemented by longitudinal investigations.

The final paper, by Weekes, Su, Yin and Zhang, examines oral reading in Mongolian–Chinese bilingual aphasics. The authors control for important variables known to impact language processing (see Paradis, 2001). If distinct brain systems mediate the reading of the alphabetic Mongolian script and non-alphabetic Chinese characters, then there may be selective disruption of written word processing. Alternatively, selective disruption may reflect variability in the use of a common system due to profeiciency and familiarity with the L2. The authors argue in favour of the latter proposal. Extending an earlier account of reading in Chinese (Weekes, Chen and Yin, 1997), Weekes and colleagues propose a common two route model for the reading of Mongolian script and Chinese: a non-semantic pathway linking input representations to phonological representations and a lexical semantic pathway that allows reading for meaning. In the normal case, both pathways may work together: the non-semantic pathway can block semantically-related reading errors and input from the lexical semantic pathway can block phonologically-related errors. Such a model readily captures impaired oral reading with intact comprehension and the reverse pattern of impaired comprehension with intact oral reading.

The conjectures and controversies discussed in the papers of this special issue signal the need for longitudinal research into the adaptive changes triggered in response to the acquisition of a new language. Longitudinal neuroimaging designs have already been applied successfully in the monolingual context to study cortical developmental changes (see Szaflarski et al., 2006) but have not been systematically used in the bilingual context. Such research will undoubtedly benefit from the explicit collaboration of linguists and cognitive neuroscientists with a view toward the development of dynamic neurocomputational models. We hope the papers here will inspire readers to take up this challenge.

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