Second Language Speech Perception and the Brain

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The theoretical framework of second language (L2) speech perception and processing is based on the nature–nurture interplay in language learning. Theories have traditionally been dominated by the critical-period hypothesis (CPH), which suggests a maturation-based constraint in learning, resulting from the loss of plasticity of the brain after puberty. Current views posit that L2 speech learning is influenced by linguistic experience, as later learning may be constrained by initial exposure to a native language (L1). Nevertheless, speech learning can improve as learners gain experience in the L2, as the mature human brain is believed to remain malleable. While the nature–nurture issues cannot be framed in all-or-none dichotomies, the debate is still current as to the extent to which speech processing and learning are influenced by linguistic experience, or reflect lower-level encoding of physical properties, as well as the extent to which they involve an interconnected system within the realm of cognitive processing. Specifically, research in L2 speech processing and learning has addressed these issues from three perspectives: (a) whether the processing of L2 speech employs specialized neural substrates and how it is influenced by experience with an L1 speech system; (b) how learning-induced plasticity is instantiated

brain potentials (ERP), by comparing the differences in the peak amplitude and latency of brain waves associated with the detection of differences in the stimuli. A particularly important ERP component in auditory speech processing is called mismatch negativity (MMN), consisting of a peak amplitude difference in the waveforms at around 150–200 ms post-stimulus onset upon detection of stimulus differences. Thus, the existence and magnitude of MMN may reflect the ability to distinguish speech sound contrasts. ERP studies have revealed that native and non-native speech processing may involve different sensory acoustic and linguistic levels, with native processing more susceptible to higher-level linguistic influence. For example, in the processing of Hindi stop consonants, an MMN was seen in Hindi but not English listeners, whereas the two groups did not differ in the ERP responses reflecting lower-level processing of acoustic signals (Sharma & Dorman, 2000). Similar processes have been shown with the processing of phonemic pitch contrasts versus within-category acoustic changes in pitch, where only the native group exhibited enhanced MMNs for phonemic differences, but response patterns to acoustic changes were the same for both native and non-native groups (Chandrasekaran, Krishnan, & Gandour, 2009b). Indeed, research has consistently revealed larger MMNs in response to the native speech contrasts than to those that are nonexistent in listeners' native phonetic inventories. These findings indicate that listeners are more sensitive to phonetic features in an L1 phonetic context, demonstrating experience-dependent neural effects in native and non-native speech processing.

Additionally, neuroimaging approaches (such as functional magnetic resonance imaging, fMRI) have been used to examine how the difference between native and non-native speech processing is localized in the brain. These techniques measure regional changes in blood flow in response to changes in neuronal activity, thus enabling localization of particular mental processes. Research has shown that the differences between native and non-native speech processing involve a network of brain regions, which go beyond the classic language areas in the left hemisphere such as Broca's and Wernicke's areas. For example, for lexical tone and vowel duration, native listeners revealed left-hemisphere activation in the pre-frontal, frontal (Broca's), temporal (Wernicke's), and parietal areas, while non-native listeners exhibited predominant right-hemisphere processing but a lesser degree of left-hemisphere involvement, even for those whose L1 was tonal. In contrast, for nonlinguistic pitch or duration patterns the native and non-native listeners exhibited similar patterns of bilateral processing in the frontal and parietal areas (Gandour et al., 2002). These findings agree with the behavioral and ERP results discussed above, indicating a language-specific top-down processing of pitch where non-native listeners' experience with acoustic cues may not be generated to higher-order linguistic processing. Moreover, the processing of different L2 linguistic speech features may involve different neural correlates depending on the nature of corresponding features in the L1. For example, while native tone-language users processed tone predominantly in the left-hemisphere temporal cortex, they processed intonation in the homologous right-hemisphere regions, presumably due to the greater linguistic functional use of tone than of intonation. In contrast, non-native listeners did not reveal any differences for the two tasks since tone was not used in their L1s (F.0109ative.d

Experience- and Learning-Induced Plasticity

Given the differences between native and non-native speech processing, one subsequent question is the extent to which the human brain has the capacity to change with continuous L2 learning. Empirical research has shown that language-related cortical responses differ as a function of experience with an L2, depending on such factors as age of L2 acquisition (AOA), L2 proficiency, and exposure to and training in the L2.

First, age has been shown to affect hemispheric lateralization for L2 speech: Learners with an early AOA tend to involve more left-hemisphere processing than do late learners (e.g., Sussman, Franklin, & Simon, 1982). Moreover, ERP research has revealed changes in MMN patterns as a function of L2 proficiency, showing that advanced rather than naive Hungarian learners of Finnish approximated native Finnish MMN patterns for processing the Finnish vowel contrasts (Winkler et al., 1999). These findings indicate experience-induced cortical differences in L2 speech processing.

One widely used method to experimentally assess the plasticity of the brain in L2 speech learning is laboratory-based perceptual training. Initial behavioral studies have shown that, after about two weeks' training, adult L2 learners can significantly improve their perception of L2 speech contrasts, suggesting that the adult human perceptual system still has the capacity to change. Consistently, ERP results have demonstrated that training can enhance the MMN responses (particularly in the left hemisphere) to L2 speech contrasts (Zhang et al., 2009). Moreover, changes in neural sensitivity due to training may be differentially affected by listeners' L1. For example, after training with Thai tones, Chinese listeners (with a tonal L1), compared to English listeners (with a nontonal L1), exhibited a larger negativity at a delayed latency, indicating that tonal L1 users were more sensitive to linguistically relevant pitch differences (Kaan, Wayland, Bao, & Barkley, 2007). Training effects have also been exhibited in the spatial domain, showing that the cortical effects of learning an L2 involve both the expansion of preexisting language-related areas and the recruitment of additional cortical regions. After training with English /r–l/, Japanese learners' improvements were associated with extended bilateral cortical and subcortical regions a shift in MMN amplitude from the right hemisphere for the initial frication noise to the left hemisphere for the later fricative–vowel transition, refl of neuroimaging techniques. It remains to be elucidated how cortical representations can be continuously shaped with learning. Future longitudinal studies tracing L2 speech learning trajectories are needed in order to define the agents of neural plasticity at various stages. Another direction for future research is to take into account individual differences. Although not yet extensively investigated, existing evidence indicates that the nature of individual processing patterns may trace the origin of speech processing as well as predicting learning success. All in all, L2 speech research addressing different stages of learning, different domains involved, and different factors affecting learning will lead us toward a complete picture in unraveling the neural mechanisms underlying L2 speech learning.

SEE ALSO

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