Research report

Neural convergence for language comprehension and grammatical class production in highly proficient bilinguals is independent of age of acquisition

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ABSTRACT

In bilinguals, native (L1) and second (L2) languages are processed by the same neural resources that can be modulated by age of second language acquisition (AOA), proficiency level, and daily language exposure and usage. AOA seems to particularly affect grammar processing, where a complete neural convergence has been shown only in bilinguals with parallel language acquisition from birth. Despite the fact that proficiency-related neuro-anatomical differences have been well documented in language comprehension (LC) and production, few reports have addressed the influence of language exposure. A still unanswered question pertains to the role of AOA, when proficiency is comparably high across languages, with respect to its modulator effects both on LC and production. Here, we evaluated with fMRI during sentence comprehension and verb and noun production tasks, two groups of highly proficient bilinguals only differing in AOA. One group learned Italian and Friulian in parallel from birth, whereas the second group learned Italian between 3 and 6 years. All participants were highly exposed to both languages, but more to Italian than Friulian. The results indicate a complete overlap of neural activations for the comprehension of both languages, not only in bilinguals from birth, but also in late bilinguals. A slightly extra activation in the left thalamus for the less-exposed language confirms that exposure may affect language processing. Noteworthy, we report for the first time that, when proficiency and exposure are kept high, noun and verb production recruit the same neural networks for L1 and L2, independently of AOA. These results support the neural convergence hypothesis.

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1.　Introduction

The acquisition of native and further languages are subserved by the same neural mechanisms, even if several factors can influence the pattern of brain involvement, such as age of acquisition (AOA), proficiency level, and the daily language exposure and usage (Perani and Abutalebi, 2005).

Late bilinguals show more extended activations around the brain areas involved in phonological and syntactic processing for the second language (L2), reflecting the need for additional neural resources to achieve a roughly native-like performance (Perani et al., 2003; Wartenburger et al., 2003; Golestani et al., 2006; Hernàndez et al., 2007; Jeong et al., 2007). Semantic processing seems to display greater stability at different AOA (Hahne and Friederici, 2001; Weber-Fox and Neville, 1996). At the other extreme, in bilinguals who learned in parallel two languages from birth, there are no differences in functional and electrical responses for both languages, particularly for grammar processing (Weber-Fox and Neville, 1996; Wartenburger et al., 2003).

High levels of proficiency produce representations of L2 that converge onto those of the native language (L1) in word production (Chee et al., 1999; Klein et al., 2006), sentence comprehension (Perani et al., 1998), and syntactic processing (Rossi et al., 2006), supporting the so-called neural convergence hypothesis (Green, 2003).

The differential exposure to languages should also have a substantial impact on the representation of L2 (Green, 1998), but this variable has been very little considered. Language exposure affects the pattern of brain activation in word production, even if both languages show a comparable level of proficiency (Perani et al., 2003). Noteworthy, the decreased exposure to a given language (even a former L1) may reduce controlled processing for that language in favor of L2 (Abutalebi and Green, 2007).

Here, we explored for the first time how AOA influences the neural correlates of sentence comprehension and word production in the same high proficient bilinguals with different AOA. Our interest was to investigate in particular whether AOA modulates the neural representation of nouns and verbs. To date, there is only one report in the literature dealing with grammatical class processing in bilinguals (Willms et al., 2011). This study focused neither on AOA nor on proficiency.

We examined two groups of Italian–Friulian bilinguals with different AOA of L2, namely at birth for the first group and between 3 and 6 years for the second group. All bilinguals had comparable high level of proficiency and exposure, but they were more exposed to Italian than Friulian.

The participants performed a combined auditory sentence comprehension and a noun–verb naming task. We expected, first, that the neural correlates for L1 and L2 comprehension overlapped in the early (from birth) high proficient bilinguals (Wartenburger et al., 2003), and, according to the neural convergence hypothesis, also in the late high proficient bilinguals (Perani et al., 1998). Second, that both noun and verb production recruit the same neural networks for L1 and L2, independently of AOA and the type of language, due to the high proficiency and exposure in both groups.

2.　Materials and methods

2.1.　Participants

Twenty-four right handed, high-proficient Italian–Friulian bilinguals took part in the functional Magnetic Resonance Imaging (fMRI) study. All subjects came from families living in Friuli Venezia Giulia, in the North-East of Italy. The participants were divided in two groups matched for age and education level. The first group comprised 12 (six females) High Proficiency Early Acquisition (HPEA) bilinguals (mean age 24.5 ± 4.3 years) who acquired Friulian and Italian since birth. The second group was composed by 12 (five females) High Proficiency Late Acquisition (HPLA) bilinguals (mean age 28 ± 4.9 years) who acquired Friulian since birth, and started learning Italian at nursery school or at primary school on average at 3.6 years (range 3–6).

All participants had no history of neurological or psychiatric illnesses and performed normal at a standard neuropsychological assessment. They gave informed consent before participating and were compensated at the rate of $35 per hour. The study was approved by the Local Ethical Committee.

2.2.　Behavioral study

The participants underwent a behavioral assessment of their language proficiency levels using the *Bilingual Aphasia Test* (BAT) in the Friulian (Paradis and Libben, 1999) and Italian (Paradis and Canzanella, 1989) versions. We chose the BAT because it is the only language test battery, which is available in Italian with an equivalent translation in Friulian. BAT subtests were classified into three categories based on the linguistic abilities they aim to assess: language comprehension (LC), naming, and metalinguistic abilities. The mean percentage of correct responses of each category was used as a measure of proficiency. More in details, LC was assessed by means of pointing, simple and semi-complex commands, complex commands, verbal auditory discrimination, syntactic comprehension, listening comprehension, reading comprehension for words, reading comprehension for sentences, reading comprehension for paragraphs, grammaticality judgments and semantic acceptability tasks. In order to test naming abilities the following BAT subtests were used: naming, sentence construction, and semantic opposite's tasks. Metalinguistic abilities were assessed with synonyms, antonyms, lexical decision, semantic category, derivational morphology, and morphological opposite's tasks.

We also assessed discourse production by means of the 'Nest Story' task, a picture description task (Paradis, 1987), in which bilingual subjects had to produce a narrative based on a cartoon story, consisting of a series of six drawings presented on the same page. The test was separately administered in Friulian and Italian to each subject. Subjects' performances were recorded and the total amount of errors (neologisms, semantic and phonemic paraphasias, anomias, and paragrammatisms) was considered. Finally, we used the fluency test (Novelli et al., 1986) as a measure of the ability to retrieve words from the lexicon.