



Language aptitude for pronunciation in advanced second language (L2) Learners: Behavioural predictors and neural substrates



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ABSTRACT

Individual differences in second language (L2) aptitude have been assumed to depend upon a variety of cognitive and personality factors. Especially, the cognitive factor phonological working memory has been conceptualised as language learning device. However, strong associations between phonological working memory and L2 aptitude have been previously found in early-stage learners only, not in advanced learners. The current study aimed at investigating the behavioural and neurobiological predictors of advanced L2 learning. Our behavioural results showed that phonetic coding ability and empathy, but not phonological working memory, predict L2 pronunciation aptitude in advanced learners. Second, functional neuroimaging revealed this behavioural trait to be correlated with hemodynamic responses of the cerebral network of speech motor control and auditory-perceptual areas. We suggest that the acquisition of L2 pronunciation aptitude is a dynamic process, requiring a variety of neural resources at different processing stages over time.

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1. Introduction

Pronunciation (speech articulation) must be considered one of the most complex human motor skills (Levelt, 1989). Presumably, the process of acquiring such a complex speech-motor skill may be obscured for first language (L1) acquisition due to its early onset in infancy and may generate the impression of an easily acquired ability. However, adult second language (L2) learners face considerable and often lasting problems with pronunciation, contrasting, eventually, with excellent knowledge of vocabulary and grammar – a dissociation of capabilities known as the “Joseph Conrad Phenomenon” (Reiterer et al., 2011). Indeed, adults vary greatly in their L2 pronunciation aptitude – both with respect to segmental (speech sounds) and suprasegmental (intonation, rhythm etc.) manifestations of spoken language (Golestani & Zatorre, 2009; Jilka, 2009a, 2009b). And it has been reported that only between 5% and 15% of adult L2 learners still manage to reach native-like

or “accent-free” speech (Birdsong, 1999, 2005; Novoa, Fein, & Obler, 1988; Seliger, Krashen, & Ladefoged, 1975; Selinker, 1972).

Language aptitude is traditionally defined as a largely innate, relatively fixed talent for learning language (Abrahamsson & Hylténstam, 2008) and is considered independent of other cognitive abilities, including intelligence (Carroll, 1993; Skehan, 1989). Among the four subcomponents of language aptitude¹ proposed by Carroll (1981), phonetic coding ability (PCA) mainly relates to pronunciation skills. PCA is defined as an ability to identify distinct sounds, to form associations between these sounds and the symbols representing them, and to retain these associations in memory. Any subject of low PCA abilities will have troubles not only in remembering phonetic material or word form, but also in mimicking speech sounds (Carroll, 1962). Sparks and colleagues (Sparks & Ganschow, 1991; Sparks, Ganschow, Javorsky, & Pohlman, 1992) have argued that tests of PCA bear a close relationship to tests for mild dyslexia. Although language aptitude as specified by Carroll's model has proved to be a good predictor for language learning ability, it does

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¹ Construct of language aptitude proposed by Carroll (1981): (1) phonetic coding ability; (2) grammatical sensitivity; (3) rote learning ability; (4) inductive language learning ability.

not provide an explanation for individual differences in L2 acquisition (Robinson, 2005).

Among the various cognitive and personality factors related to pronunciation talent (Dörnyei, 2006), phonological working memory (PWM) is considered one of the most salient predictors of L2 aptitude (Baddeley, 2003; Baddeley, Gathercole, & Papagno, 1998; Miyake & Friedman, 1998). PWM specialises in the retention of verbal information over short periods of time (Baddeley, 1986), and comprises both a phonological store that holds information in phonological form, and sub-vocal articulatory rehearsal that is capable of refreshing the memory trace to prevent its decay (Baddeley, 1990). A variety of behavioural data indicate PWM to be associated with the ability of learning unfamiliar phonological forms (Atkin & Baddeley, 1998; Baddeley, 1993; Baddeley, Papagno, & Vallar, 1988; Gathercole, Service, Hitch, Adams, & Martin, 1999; Papagno, Valentine, & Baddeley, 1991; Service, 1992). As a consequence, this system might serve, among other things, as a language learning device (Baddeley et al., 1998). The network of brain areas bound to PWM include a storage component located in the left supramarginal gyrus (SMG)/inferior parietal lobe, and a rehearsal mechanism involving Broca's area (Awh, Smith, & Jonides, 1995; Baldo & Dronkers, 2006; Chein & Fiez, 2001; Fiez et al., 1996; Henson, Burgess, & Frith, 2000; Koelsch et al., 2009; Paulesu, Frith, & Frackowiak, 1993; Vallar, 2006; Vallar, Di Betta, & Silveri, 1997). The PWM circuit has also been found to overlap with cerebral networks engaged in speech perception and speech production (Aboitiz, Garcia, Bosman, & Brunetti, 2006; Acheson, Hamidi, Binder, & Postle, 2011; Acheson & MacDonald, 2009; Ackermann, 2008; Hickok, Buchsbaum, Humphries, & Muftuler, 2003; Hickok & Poeppel, 2007; Reiterer, Erb, Grodd, & Wildgruber, 2008). Currently, the association between PWM and language learning is widely accepted in the fields of psycholinguistics and neurosciences. However, the PWM model cannot account for two important issues of L2 acquisition: (a) the differences between early and late language learners and (b) the role of overt speech articulation.

(a) Since language learning represents a dynamic process, somewhat different predictors for early and more advanced stages of L2 acquisition must be expected (Carroll, 1990; Robinson, 2005). A strong relationship between behavioural measures of PWM, such as digit span or pseudo-word repetition, and language learning abilities could be documented for early-stage learners only, while this association was found to decline in advanced learners (Gathercole, 2006; Masoura & Gathercole, 2005). A previous study of our group was able to confirm that PWM and hemodynamic activation of the respective brain regions, i.e., SMG and Broca's area, predict pronunciation aptitude of early-stage L2 learners (Reiterer et al., 2011). However, the cognitive and personality factors impacting advanced learners still remain to be determined. Previous literature refers to music aptitude (Nardo & Reiterer, 2009; Novoa et al., 1988; Slevc & Miyake, 2006), intelligence (Novoa et al., 1988; Rota & Reiterer, 2009), as well as personality factors (Dörnyei, 2006; Hu & Reiterer, 2009) such as empathy (Guiora & Acton, 1979), extraversion (Dewaele & Furnham, 1999, 2000) and openness to experience (Verhoeven & Vermeer, 2002). Thus, cognitive and personality factors other than PWM may influence advanced L2 learning.

Music aptitude was found to predict both perceptive and productive L2 phonological ability in a group of Japanese immigrants in USA (Slevc & Miyake, 2006). Phonological and musical processing might have similar neural underpinnings. Musicians with absolute pitch showed significantly more hemodynamic activation – compared to those without absolute pitch – in speech-relevant areas such as superior-temporal regions during perception tasks addressing speech prosody (Oechslin, Meyer, & Jäncke, 2010). Passive listening to classical music activated the

language area inferior frontal gyrus (IFG) (Levitin & Menon, 2003; Maess, Koelsch, Gunter, & Friederici, 2001). Working memory tasks with verbal materials and with musical materials showed similar activation patterns (Koelsch et al., 2009). Moreover, professional musicians were found to have morphological changes in the speech relevant cortical regions such as planum temporale (PT) and Heschl's gyrus (HG) (Keenan, Thangarai, Halpern, & Schlaug, 2001; Luders, Gaser, Jäncke, & Schlaug, 2004; Schlaug, Jäncke, Huang, & Steinmetz, 1995; Schneider et al., 2005; Wilson, Lusher, Wan, Dudgeon, & Reutens, 2008).

An association between empathy and the capacity for mastery of L2 pronunciation was reported in several studies (Guiora, 1967; Guiora, Beit-Hallahmi, Brannon, Dull, & Scovel, 1972; Guiora, Taylor, & Brandwin, 1968; Taylor, Guiora, Catford, & Lane, 1969). It was suggested that both empathy and L2 pronunciation capacity were influenced by the same underlying process – permeability of “ego boundary” (Guiora & Acton, 1979). More recently the discovery of mirror neurons has provided another possible explanation to the process of language acquisition. Other than the elusive concept “ego boundary”, the neurophysiologically grounded “mirror neuron system” might be the underlying link. The Mirror neuron system has been suggested to be important in language development (Rizzolatti, 2005) and the neural network for empathy is suggested to be composed of the mirror neuron system, the insula, and the limbic system (Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Iacoboni, 2009). Empirically, regions of prosody perception and production were found in premotor regions, and activity in these regions was further found to correlate with individual differences in empathy (Aziz-Zadeh, Sheng, & Gheytanchi, 2010). Interestingly, imitation of accent improved language comprehension (Adank, Hagoort, & Bekkering, 2010), and the language comprehension in social context largely relates to empathy (Van den Brink et al., 2010).

As its first purpose, the present study tries to determine the behavioural factors predicting L2 pronunciation aptitude in more advanced learners, i.e., adults with an onset of L2 learning at around an age of 10 years and more than 10 years of exposure to L2 (for the association between language/pronunciation aptitude and other cognitive/personality factors see Dewaele, 2009; Dörnyei, 2006; Hu & Reiterer, 2009; Sparks & Ganschow, 2001). Previous neuroimaging studies of language learning can be classified into investigations of early-stage learning or more advanced learning. fMRI Experiments with early-stage learners have shown negative relationships between phonetic learning performance and the activation in insula/IFG areas and temporal areas during phonetic identification/perception tasks (Golestani & Zatorre, 2004; Wilson & Iacoboni, 2006; Wong, Perrachione, & Parrish, 2007), also in IFG and SMG during imitation tasks (Reiterer et al., 2011). For the advanced learners, better performance in phonetic identification was associated with higher hemodynamic activation in a network encompassing left insula/IFG and temporal areas, SMG, cerebellum and basal ganglia during a phonetic identification task (Callan, Jones, Callan, & Akahane-Yamada, 2004). Highly proficient bilingual subjects also displayed enhanced responses – as compared to low-aptitude individuals – at the level of the insula (Chee, Soon, Lee, & Pallier, 2004) and premotor areas (Majerus et al., 2008) during working memory tasks. The different directions of the activation-aptitude association might indicate different underlying neural mechanisms between early-stage and advanced learners.

(b) Learning to speak essentially represents a motor skill acquisition task (Hickok & Poeppel, 2007) – reaching beyond the elaboration of auditory perception and memory capabilities into the domain of motor development (Seibert, 1927). Language teaching experiments demonstrated, e.g., that L2 learning could be improved by enhancing an overt rehearsal strategy (Ellis &

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