NEURAL PREDISPOSITION FOR L2 STRESS LEARNING IN FRENCH AND GERMAN LISTENERS

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ABSTRACT

The present research examines the neural predisposition for L2 stress learning, and investigates whether this predisposition is driven by the learners' native language (free- vs. fixed-stressed). fMRI and behavioral experiments were run with French- and German-speaking listeners. Participants performed stress-related tasks in Spanish (an unknown language), and underwent a perceptual training on Spanish stress contrasts. Results showed a different relationship between the training effect and the degree of neural activation for both groups. German listeners with larger activation in fronto-temporal areas were more successful in learning L2 stress, whereas such relationship could not be observed for French listeners.

Keywords: L2 stress perception, neural predisposition, language-dependent, fronto-temporal regions.

1. INTRODUCTION

Besides cognition- and rhythm-related factors (e.g., working memory or phonological awareness; musical expertise; [1], [2]), the listeners' native language (L1), and more specifically, its stress properties, have a considerable influence on the listeners' ability to process stress in a foreign language ([1], [4], [5]). Native speakers of languages with predictable (also called 'fixed') stress (e.g., French) have been shown to experience larger difficulties in discriminating lexical stress contrasts in a foreign/second language (hereafter 'L2') (e.g., en. import versus import; es. número versus numero)[1] than speakers of languages with variable (also called 'free') stress (i.e., English, German) ([3], [4]).

With the specific goal to improve the listeners' ability to perceive accurately L2 sounds or contrasts, perceptual training is used for learning not only segmental, but also suprasegmental features. Importantly for the present study, recent research has shown that learners were able to partly overcome their L2 stress detection difficulties thanks to specific perceptual training, although with a certain amount of interindividual variability ([6]). Besides the behavioral factors that might influence L2 stress perception and learning ability, the existence of neural predisposition for prosodic learning is also conceivable.

To date, neuroimaging studies on a possible neural predisposition for prosodic learning are still very scarce. However, there seems to be evidence that working memory, encompassing its two key components phonological and executive working memory, is a strong predictor of language aptitude ([7], [8]). Furthermore, neuroimaging studies show that phonetic learning performance is associated with activation in the inferior frontal gyrus (IFG) and temporal areas, including the superior temporal gyrus (STG) ([9], [10], [11]), which seems to be involved in high-order auditory processing of speech ([12]). Of particular interest for the present study is the research carried out by [11] on L2 tone perception, showing brain activation differences in superior temporal regions even before training between 'successful' (i.e., participants who profited more from training) and 'less successful' learners.

The present research is the first attempt to examine the neural predisposition for L2 stress learning, and to investigate whether this predisposition is driven by the learners' native language (free- vs. fixed-stressed). The question to be answered is whether, as previously shown for L2 tone learning, there is a relationship between the training effect and the activation in frontal and temporal brain areas during L2 stress processing, and to what extent this relationship depends on the learners' native language.

2. METHOD

2.1. Participants

Two groups of participants took part in the study. Forty-six participants were native speakers of French (hereafter 'FR') aged between 18 and 28 years (M = 23.1, SD = 2.41; 27 females). Thirty-five participants were native speakers of (Swiss) German (hereafter 'DE') aged between 19 and 28 years (M =

[1] The underlined syllable in these examples, and in the rest of the paper, corresponds to the stressed syllable.

22.6, *SD* = 2.34; 26 females). All participants were students from Fribourg or Bern universities. They had no knowledge of Spanish, Italian, or Portuguese (i.e., free-stress romance languages). Bilingual participants, who learned another language than French or (Swiss) German before the age of 6, were not included. However, since French, German and English are mandatory disciplines in the Swiss educational system. DE had school knowledge of French and English and FR school knowledge of German and English. Participants were paid for their participation. The study was approved by the Ethics Committee of the Psychology Department of University of Fribourg.

2.2. Experimental design

Participants took part in four experimental sessions (see Figure 1). In sessions 1 and 2, they performed an fMRI experiment and a behavioral experiment (i.e., pretest), respectively. In session 3, participants were administered a perceptual training on Spanish stress contrasts. In session 4, they performed the behavioral experiment again (i.e., posttest).

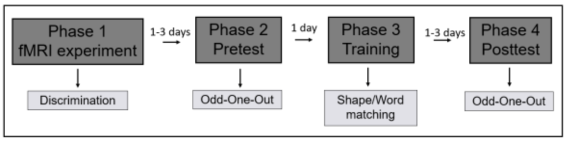

Figure 1: Experimental design.

2.3. fMRI experiment

2.3.1. Material and procedure

In the fMRI experiment, participants performed the discrimination task described in [13]. Participants were presented with pairs of auditory trisyllabic Spanish words produced by a female native speaker of Castilian Spanish. They were asked to indicate whether the two Spanish words were the same or different. In the 'different' pairs, items differed either in the final vowel of the word (e.g., valoro versus valore) or in the position of word stress (e.g., valoro versus valoró). In the 'vowel' deviating pairs, one of the items was always the 1sg present indicative of the verb (e.g., valoro, en. I value) and the other item the 1sg or 3sg present subjunctive of the same verb (e.g., valore, en. that I/he/she value). The 'stress' deviating pairs were composed of the 1sg present indicative of the verb (e.g., valoro, en. I value) and 3sg simple past tense of the same verb (e.g., valoró, eng. he/she valued). The usage of identical verbs for the vowel and stress conditions ensured similar lexical properties across both conditions (bypassing the potential confounding factors of lexical frequency, phonological neighborhood and cognateness). The vowel and stress conditions were presented alternatively using a block design. The vowel condition served as a control condition to be compared with the stress condition.

2.3.2. Data acquisition and pre-processing

MRI data collection included two fMRI runs of 9 minutes that were acquired successively with a 3T GE scanner (acquisition details: TR = 2000 ms, TE = 30 ms, flip angle = 85°, voxel size = 2.3 x 2.3 x 3 mm). MRI data preprocessing and analyses were conducted with SPM12 (UCL, London). Functional images were preprocessed with a standard pipeline (slice timing, spatial realignment and unwarping, co-registration of anatomic scan on fMRI, Unified-segmentation of anatomic scan, normalization, smoothing). The resulting images were analyzed at the individual subject level using a general linear model (GLM). fMRI signal was modelized as condition-specific block of 22.63s of duration convolved with the hemodynamic response function (HRF). A high-pass filter with a 1/128 Hz threshold was applied at time series to remove low frequency noise and signal drifts and an autoregressive function (AR(1)) was implemented to correct temporal correlations between neighboring voxels.

2.3.3. Data analysis

The contrast between Stress and Vowel blocks was sent to a one-sample t-test to study the difference of brain activity between the two conditions. Based on previous research ([13], [14], [15]), brain activation differences were extracted in the following regions of interest: left and right inferior frontal gyrus (IFG) as well as left and right superior temporal gyrus (STG). The higher the value, the larger the activation difference between Stress and Vowel.

2.4. Behavioral experiment

2.4.1. Pre-/posttests

In the pre- and posttests, participants performed the Odd-One-Out task described in [6]. They heard trials of three trisyllabic Spanish words (e.g., valido-validó-valido) and had to indicate which of the three words differed regarding the stress pattern. The pretest included 216 trials comprising different degree of talker and intonation variability (see [6] for details), while the posttest included the same trials as in the pretest as well as 108 additional trials composed of novel words produced by two novel female speakers. For each participant, percent correct for pre-, posttest as well as for novel items was collected, and the training effect was calculated by subtracting pretest percent correct to posttest percent correct. We also computed the difference between correct percent at posttest with novel items and pretest percent correct.

2.4.2. Training

Training focused only on the perception of stress contrasts in Spanish. We used the non-explicit training developed by [6] that was divided into eight 30-minute sessions and administered with Praat ([16]) over two weeks, at the participants' place. Six Spanish words, produced by two Castilian Spanish female speakers, were used: two first-syllable (i.e., cáscara and género), two second-syllable (i.e., cascara and genero) and two third-syllable stressed words (i.e., cascará and generó). We also created six shapes (similar to Tetris shapes), each one associated to each of the six words. It is important to mention there was no direct relationship between the stress patterns of the words and the shapes (i.e., a word with stress on the first syllable was not necessarily associated with a shape with a 'peak' in its left part). Without receiving previous metalinguistic explanation about Spanish accentual system, the participants performed a shape/word matching task during the entire duration of the training. In this task, they heard one of the six Spanish words and four shapes appeared on the screen. They had to click on the shape they thought corresponded to the word they heard. After giving their response, they received feedback: they heard the word again and only the correct shape stayed on the screen. The feedback allowed the participants to learn the correspondence between the words and the shapes. The outcome measures of the training were not further analyzed.

2.5. Data analysis

Unpaired t-tests were used to test the difference between FR and DE regarding training effect, and neural activation in the four brain regions under study. One-sample t-tests were used to test the training effect on novel trials in FR and DE. Finally, correlations were run separately for FR and DE between training effect and neural activation in each region of interest.

3. RESULTS

3.1. Effect of L1 on training effect with validation

As shown in Figure 2, training effect did not differ between FR and DE (*M* = 8.036, *SD* = 5.872 and *M* = 7.865%, *SD* = 7.068, respectively; t(79) = 0.115, p = .908), although FR performed more poorly than DE at pretest (*M* = 50.936%, *SD* = 15.862 and *M* = 74.643%, *SD* = 9.834 respectively; t(79) = -8.262, p <.001). The difference between percent correct at pretest and at posttest with novel items was significantly different from 0 for FR (*M* = 11.051; *SD* = 8.828; t(45) = 8.490, p < .0001) and for DE (*M* = 9.166; *SD* = 87.355; t(34) = 7.373, p < .0001) This indicates that FR and DE's performance improved after training even on items that were new to the listeners, and thus validates the efficiency of the training method.

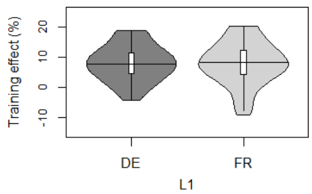

Figure 2: Training effect (%) as a function of L1.

3.2. Effect of L1 on neural activation

As observed in Figure 3, FR exhibited stronger activation than DE in the left IFG (*M* = 0.359, *SD* = 0.258 and *M* = 0.231, *SD* = 0.214 respectively; t(79) = 2.370, p = .020) as well as in the right IFG (*M* = 0.567, *SD* = 0.334 and *M* = 0.341, *SD* = 0.264, respectively; t(79) = 3.300, p = .001). In contrast, the activation for FR and DE did not differ in left STG (*M* = 0.112, *SD* = 0.194 and *M* = 0.109, *SD* = 0.177, respectively; t(79) = 0.055, p = .956) and the right STG (*M* = 0.190, *SD* = 0.242 and *M* = 0.121, *SD* = 0.195, respectively; t(79) = 1.373, p = .174).

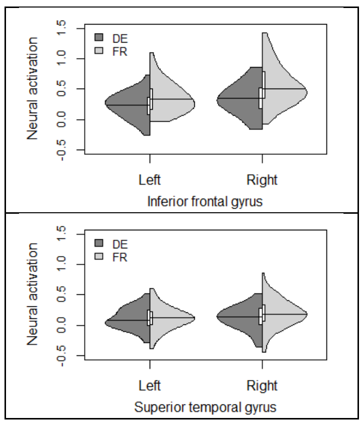

Figure 3: Neural activation in bilateral IFG (top) and STG (bottom) as a function of L1.

3.3. Relationship between neural activation and training effect in DE and FR

As apparent in Figure 4, DE listeners presented a (marginal) relationship between neural activation and training effect for both left IFG (r(33) = .313, p = .067) and right IFG (r(33) = .318, p = .062): the stronger the activation in the bilateral IFG, the larger the training effect. No such link was confirmed for FR listeners, neither in left IFG (r(44) = .192, p = .202), nor in right IFG (r(44) = -.03, p = .841).

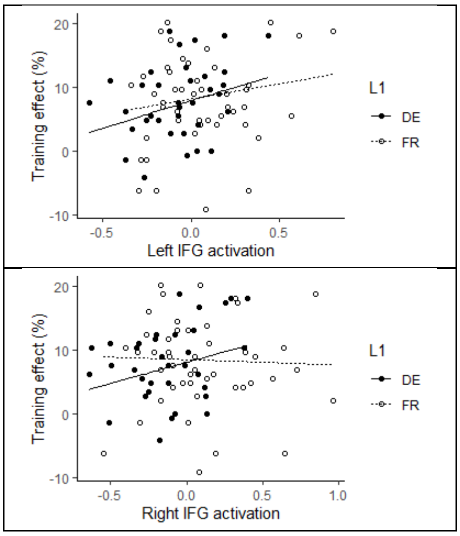

Figure 4: Training effect (%) as a function of neural activation in left and right IFG for DE and FR listeners.

As can be seen in Figure 5, the relationship between the left STG activation and the training effect was significant for DE ($r(33) = .442$, $p = .008$), but not for FR ($r(44) = -.028$, $p = .855$). The same pattern was observed for the right STG (DE: ($r(33) = .382$, $p = .023$); FR: $r(44) = -.038$, $p = .8$), confirming that the training effect increased with larger STG activation in DE, but not in FR.

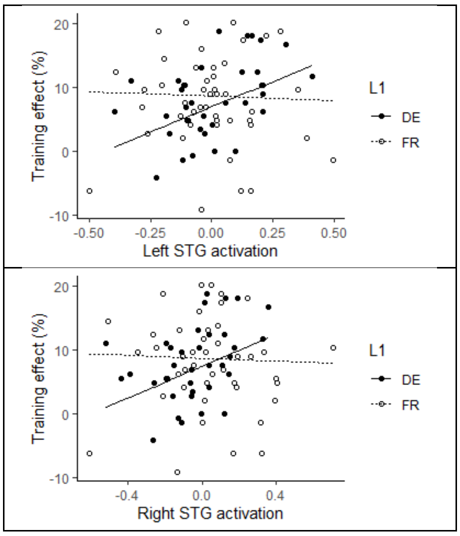

Figure 5: Training effect (%) as a function of neural activation in left and right STG for DE and FR listeners.

4. DISCUSSION

The present research aimed to examine the neural predisposition for L2 stress learning in French- and German-speaking listeners. Results from our behavioral experiment showed that although the French group performed overall more poorly at the pretest than the German group, a similar training effect was found for both groups. Such a training effect confirms previous results with French listeners ([6]). Furthermore, it suggests that not only speakers of languages with predictable stress but also speakers of variable stress languages benefit from a short perceptual training to improve their stress discrimination abilities in a foreign language with variable stress.

As for neural activation, French listeners showed a higher degree of activation in the left and right IFG than German listeners. In line with [15], the involvement of areas associated with cognitive control and working memory ([17]) was stronger for French than German listeners, suggesting larger cognitive resource demands for participants of a fixed-stress native language. On the other hand, neural activation in the bilateral STG did not differ between both language groups, suggesting similar auditory and word stress processing ([18], [19]) for French and German listeners.

Interestingly, our findings showed a different relationship between the training effect and the degree of neural activation in the two language groups. The stronger the engagement in areas associated with cognitive control and working memory (i.e., IFG), the larger the amount of improvement after training for L1 German participants, but not for L1 French participants. As for temporal activation, results showed a similar pattern. For L1 German listeners only, the larger the activation related to stress auditory processing (i.e., STG), the larger the training effect. No such relationship between strength of activation and training effect was found for L1 French listeners.

Taken together, our findings suggest a neural predisposition for L2 stress learning for L1 German listeners. German listeners with larger activation in fronto-temporal areas were more successful in learning L2 stress. In contrast, such a neural predisposition could not be observed for French listeners. The relationship between the amount of improvement after training and the degree of neural activation during L2 stress processing seems thus to be driven by the learners' native language. Our results therefore suggest that the neural predisposition for L2 stress learning comes along with the fact of having a native language with variable stress. Such an assumption however needs to be further explored with native learners of other free- and fixed-stress languages.

The present research reveals that the link between neural correlates of L2 stress processing and the amount of improvement after training might be specific to the learners' native language (fixed- vs. free-stress), even in case of similar average progression after training.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Honbolygó, F., Kóbor, A., Csépe, V. 2019. Cognitive components of foreign word stress processing difficulty in speakers of a native language with non-contrastive stress. *International Journal of Bilingualism*, 23(2), 366–380. https://doi.org/10.1177/1367006917728393

[2] Degrave, P. 2017. Can music help learners and teachers in word stress perception? *Travaux du Cercle Belge de Linguistique*, 11, 1-20.

[3] Dupoux, E., Pallier, C., Sebastián, N., Mehler, J. 1997. A destressing 'deafness' in French? *J. Memory Lang*., 36(3), 406-421,

[4] Schwab, S., Dellwo V. 2017. Intonation and talker variability in the discrimination of Spanish lexical stress contrasts by Spanish, German and French listeners. *J. Acoust. Soc. Am.*, 142 (4), 2419–2429, 2017.

[5] Ortega-Llebaria, M., Gu, H., Fan, J. 2013.English Speakers' Perception of Spanish Lexical Stress: Context-Driven L2 Stress Perception. *J. Phon*., 41, 186–97, 2013.

[6] Schwab, S, Dellwo, V. 2021. Explicit versus non-explicit prosodic training in the learning of Spanish L2 stress contrasts by French listeners. *Journal of Second Language Studies*, 2021. http://doi.org/10.1075/jsls.21017.sch.

[7] Grymska, B. 2016. New Conceptualizations of Language Aptitude—The Potential of Working Memory in Second Language Acquisition (SLA). *Theory and Practice of Second Language Acquisition*, 2(1), 103-118.

[8] Wen, Z. E. 2019. Working memory as language aptitude: The phonological/executive model. In *Language Aptitude* (pp. 187-214). Routledge.

[9] Callan, D. E., Jones, J. F., Callan, A. M., Akahane-Yamada, R. 2004. Phonetic perceptual identification by native- and second-language speakers differentially activates brain regions involved with acoustic phonetic processing and those involved with articulatory–auditory/orosensory internal models, *NeuroImage*, 22 (3), 1182-1194.

[10] Golestani N., Zatorre, R.J. 2004. Learning new sounds of speech: reallocation of neural substrates. *Neuroimage*, ;21(2):494-506. doi: 10.1016/j.neuroimage.2003.09.071.

[11] Wong, P. C. M, Perrachione, T. K., Parrish T. B. 2007. Neural characteristics of successful and less successful speech and word learning in adults. *Human Brain Mapping*; 28(10), 995–1006.

[12] Mesgarani, N., Cheung, C., Johnson, K., Chang, E. F. 2014. Phonetic Feature Encoding in Human Superior Temporal Gyrus. *Science*, 343 (6174), 1006-1010.DOI: 10.1126/science.1245994

[13] Schwab, S., Mouthon, M., Jost, L., Salvadori, J., Stefanos-Yakoub, I., Ferreira da Silva, E., Giroud, N., Perriard, B., Annoni, J.-M. in press. Neural correlates of lexical stress processing in a foreign free-stress language. Brain & Behavior.

[14] Klein, E., Domahs, U., Grande, M., Domahs, F. 2011. Neuro-cognitive foundations of word stress processing—Evidence from fMRI. *Behavioral and Brain Functions*, 7(1), 15. https://doi.org/10.1186/1744-9081-7-15

[15] Rogenmoser, L., Mouthon, M., Etter, F., Kamber, J., Annoni, J.-M., & Schwab, S. (2022) The processing of stress in a foreign language modulates functional antagonism between default mode and attention network regions. bioRxiv; doi: https://doi.org/10.1101/2022.12.21.521156

[16] Boersma, P. 2001. Praat, a system for doing phonetics by computer. *Glot International*, 5:9/10, 341-345.

[17] Fedorenko, E., Blank, I. A. 2020. Broca's area is not a natural kind. *Trends in Cognitive Sciences*, 24(4), 270-284.

[18] Aleman, A., Formisano, E., Koppenhagen, H., Hagoort, P., de Haan, E. H. F., Kahn, K. 2005. The functional neuroanatomy of metrical stress evaluation of perceived and imagined spoken words. *Cereb.Cortex*, 15, 221-228.

[19] Domahs, U., Klein, E., Huber, W., Domahs, F. 2013. Good, bad and ugly word stress – fMRI evidence for foot structure driven processing of prosodic violations. *Brain and Language*, 125(3), 272-282. https://doi.org/10.1016/j.bandl.2013.02.012.