Lexically-guided phonetic recalibration transfers across languages in French-English bilinguals

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ABSTRACT

Lexically-guided phonetic recalibration results from exposing listeners to an ambiguous sound (e.g., a sound between /f/ and /s/) embedded in real words disambiguating the sound (as in 'beautiful'). After repeated exposure to the sound in various /f/-words, listeners shift their perception even in the absence of disambiguation [1]. Recalibration was shown to transfer across Germanic languages in advanced L2 learners [2]. Here we replicate this result in French-English bilinguals.

Fifty French-English bilinguals from Montreal, Canada, were tested online. Groups 1 and 2 had exposure in English toward /f/ and /s/ respectively, while Groups 3 and 4 had exposure in French. The perceptual shift was then assessed in both languages.

A perceptual shift occurred in all groups and transferred across languages. This suggests that French-English bilingual listeners have one common phonemic category for similar sounds across languages.

Keywords: bilingualism; perceptual learning; phonetic recalibration; speech perception; transfer;

1. INTRODUCTION

The lexical recalibration paradigm results from exposing a listener to an ambiguous sound, hereafter /?/ - for instance a sound between /f/ and /s/ - embedded in real words (e.g., "beautiful") that disambiguate the sound [1]. The ambiguous sound will not only be perceived as /f/ in this context but even in the absence of disambiguation [1], [3]. For instance, a repeated exposure to the ambiguous sound /?/ replacing the sound /f/ in real words will produce a shift of the perceptual boundary between /f/ and /s/. The boundary is expected to shift toward /s/, resulting in more /f/ responses in a subsequent identification task. By contrast, s-words like the item "curren/?/y" will be expected to trigger a shift in the opposite direction, as "currency" is an existing word while "currenfy" is not.

Previous work has shown that lexically-guided phonetic recalibration in advanced L2 learners transfers from L2 English to L1 Dutch [2] or L1 German [4]. This suggests that the phonetic systems of these listeners are shared between their languages or at least linked. In the present study we investigated whether this result could be replicated with French-English bilinguals. These languages are more distant topologically as they belong to different language groups (English being part of Germanic languages while French belongs to the Romance language family).

2. METHOD

2.1. Participants

Fifty French-English bilinguals (age: 18-40; French AoA=0; English AoA range = 0-12 years-old) from Montreal, Canada, were tested online. They were screened for their language experience and proficiency with a subset of the LEAP-Q (Language Experience and Proficiency Questionnaire - Marian, Blumfield, & Kaushanskaya, 2007). There was a headphone screening before the experiment to make sure they were wearing headphones or earbuds [6].

2.2. Design

Participants were divided into four groups. Groups 1 and 2 had exposure in English toward /f/ and /s/ respectively, while Groups 3 and 4 had exposure in French toward /f/ and /s/ respectively.

2.3. General procedure

The procedure consisted of two phases: an exposure phase and a post-test.

The exposure phase was an auditory lexical decision task in which stimuli differed across groups as explained in the Design section. On each trial, participants heard an auditory stimulus and they had to indicate if what they heard was a real word or not by pressing one of two keys on their keyboard. The critical items containing the ambiguous /f/-/s/ sound (either f-words or s-words) were presented among fillers.

The post-test aimed to characterize the category boundary between /f/ and /s/ in both French and English. It was an identification (categorization) task, in which participants heard tokens on a continuum between two words constituting a minimal pair (e.g., "found" and "sound"). Participants heard a token and had to indicate whether they heard /found/ or /sound/ by pressing a key. The post-test consisted of four blocks of 40 trials each (4 minimal pairs * 5 steps on the continuum * 2 repetitions), alternating between French and English. The language of the first block was counterbalanced across participants.

2.4. Stimuli

All stimuli in French and English were recorded by the same French-English bilingual talker, recruited in the Montreal area.

The stimuli of the exposure phase consisted of 36 critical items (18 /f/-words and 18 /s/-words), 36 fillers matched in length and frequency with critical items, and 72 pseudo-words. There were thus 144 stimuli per language.

Critical items were selected with the following criteria: /f/ or /s/ had to appear as late as possible in the word (ideally as the onset of the 3rd or 4th syllable); /f/ or /s/ should not appear in a consonantal cluster (for instance /fr/ or /sl/); words had to be as frequent as possible to maximize recalibration; cognates (words that are phonologically similar between French and English) had to be avoided. A f-version and a s-version of each critical item were recorded (e.g. 'beautiful' and 'beautisul', or 'currecy' and 'currenfy'). A 10-step continuum was created for each pair using a Matlab script that synthesizes weighted combinations of LPC-characterized end-points [7]. The fricatives were extracted, made equal in duration and then merged by morphing LPC coefficients. Formant transitions in the vowel following fricatives were also merged so that resulting formants were the weighted average of formants from both f-version and s-version recordings. These tokens were piloted to find the most ambiguous token in each continuum - the one for which the proportion of /f/ responses is the closest to 0.5. Six French native speakers performed an identification task on these continua, where they had to say if they heard /f/ or /s/, with 4 repetitions by token. English tokens were selected the same way with six English native speakers.

English f-words	French f-words
barefoot	*agrafer*
battlefield	*analphabète*
beautiful	*anglophones*
benefit	*approfondir*
counterfeit	*bénéfique*
delightful	*biographie*
identify	*confiture*
manifold	*décoiffer*
pocketful	*ébouriffé*
purify	*emberlificoter*
qualify	*haltérophile*
quantify	*imparfait*
radiography	*indifférent*
ungrateful	*mammifère*
uniform	*montgolfières*
unprofitable	*nénuphar*
waterfall	*réconfort*
wonderful	*triomphant*

English s-words	French s-words
accuracy	*angoissant*
countersign	*compréhensible*
cumbersome	*déboussolé*
currency	*débroussailler*
democracy	*déconcerté*
innocent	*dépoussiérer*
legacy	*éclaboussure*
noticeable	*éclaircir*
policy	*endurci*
precursor	*épanouissant*
pregnancy	*garçon*
producer	*intarissables*
pronouncing	*menacer*
reconcilable	*raccourci*
reducing	*ralentisseur*
rehearsal	*ramasser*
troublesome	*reconnaissant*
undersea	*remerciement*
underside	*tournesol*

Table 1: Critical items used in the exposure.

For the post-test, four minimal pairs that differ only on the /f/-/s/ contrast with various vocalic contexts were selected in both languages (in English: *feel/seal, for/soar, fine/sign, found/sound* and in French: *feuille/seuil, fil/cil, fort/sort* and *fond/son*). A 20-step continuum was created for each pair using the same procedure as for critical items [7].

The stimuli were also piloted with the same native speakers to find the most ambiguous token in each continuum - the one for which the proportion of /f/ responses is the closest to 0.5. The 5 steps selected for the post-test were the most ambiguous stimuli (MAS) along with MAS -5, MAS -2, MAS+2 and MAS+5. For instance, if the most ambiguous stimulus was step 8, then the selected steps were steps 3, 6, 8, 10 and 13 on the 20-step continuum. In the Results section these steps are relabelled from 1 to 5.

The pseudowords were generated using the multilingual pseudoword generator Wuggy [8]. They were matched in length and syllable frequency with real words (critical items and filler words). All exposure items contained no fricative except a single /f/ or /s/ in each critical items.

2.5. Data analysis

Data was analysed using General Linear Mixed Models with the *glmer* function from the *lme4* package in R. The variable *resp* is a binary variable which equals 1 when participants press the /f/ button and 0 when the /s/ button is pressed. This variable was modeled as follow:

*resp ~ recalibration_language * direction * test_language + step + (test_language|Participant) + (1|minimal_pair)*

recalibration_language (English or French), and *direction* (recalibration toward /f/ or /s/) are between-subject variables while *test_language* (English or French) and *step* (from 1 to 5) are within-subject variable. *participant* was included as a random factor. We followed a backward deletion approach [9] to select the best model using likelihood ratio tests. Post hoc tests were adjusted for multiple comparisons, with the *glht* function from the *multcomp* package of R [10].

2.6. Operational hypothesis

We expected that recalibration would occur in all groups. We thus predicted that groups exposed to f-words with an ambiguous sound between /f/ and /s/ (Groups 1 and 3) would perceive more /f/ in the post-test (with continua made from minimal pairs) than Groups exposed to ambiguous s-words during the recalibration phase.

We wanted to investigate whether there would be some transfer across languages, and if so, whether there would be full transfer? Transfer across languages occurs when there is a significant shift even when the test language is not the same as the recalibration language. A full transfer would occur if the magnitude of the shift is the same regardless of whether test language and recalibration are the same or different.

3. RESULTS

Figure 1 represents the proportion of /f/ responses across Groups (recalibration language and direction being between-subjects factors) in the post-test over the 5-step f-s continua. It shows that Groups 1 and 3, which were exposed to ambiguous sounds in f-words, tend to give more f responses than groups 2 and 4 which were exposed to ambiguous sounds in s-words.

The model that best fitted the data was *resp ~ direction + test_language + step* There was an effect of the direction of the recalibration (toward /f/ or toward /s/) and an effect of the language in the post-test with no interaction between those factors.

However there was no effect of the recalibration language (p=0.57). This absence of effect suggests that there was a transfer of recalibration across languages and that this transfer was nearly a full transfer. Figure 2 clearly illustrates that the recalibration is equivalent when post test language is the same as exposure or not.

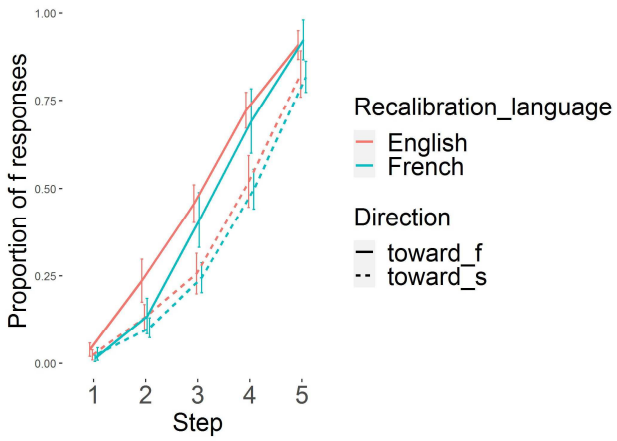

Figure 1: Proportion of /f/ responses across groups in the post-test. The x-axis represents the 5 steps on the /f/-/s/ continuum. The error bars give standard errors.

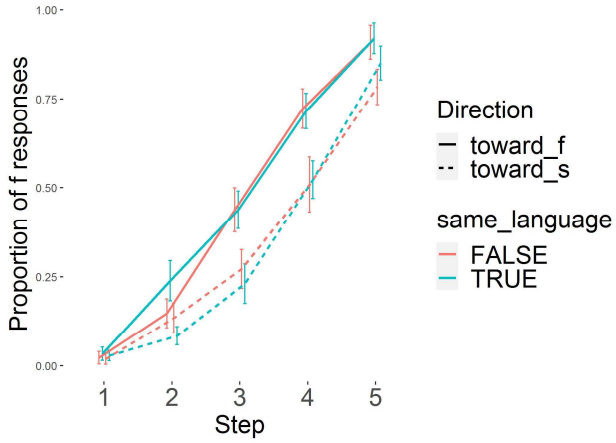

Figure 2: Proportion of /f/ responses given the direction of the recalibration and whether the post-test language is the same as the recalibration language or not. The gap between the two blue lines represents the recalibration in the same language while the gap between the red lines represents the transfer of recalibration from one language to another. The x-axis represents the 5 steps on the /f/-/s/ continuum. The error bars give standard errors.

Post hoc comparisons revealed that participants who had exposure toward /f/ gave significantly more /f/ responses than participants who had exposure toward /s/ (0.52±0.18; z=2.94; p=0.006). This main effect confirms that recalibration occurred. Post hoc comparison also indicate that the proportion of /f/ responses was higher when tested on French minimal pairs than when tested on English minimal pairs (0.43±0.07; z=6.36; p<0.001).

4. DISCUSSION

In the present study, we wanted to investigate whether perceptual learning, more specifically lexically-guided phonetic recalibration, transfers across languages in French-English bilinguals.

We had four Groups with different exposure conditions. Groups 1 and 3 had exposure toward /f/ while Groups 2 and 4 had exposure toward /s/. Groups 1 and 2 had exposure in French while Groups 3 and 4 had exposure in English. All groups were then tested on their perception of /f/-/s/ continua in both English and French minimal pairs, to assess their perceptual boundary between /f/ and /s/ in each language.

There was no effect of the exposure language (French vs English) on the proportion of /f/ responses. This confirmed our prediction: there was a perfect transfer of recalibration from English to French and vice versa. This replicates the study by c which observed similar magnitude in the shift triggered in L1 by exposure in L2 and the shift induced by L2 on L1. This result indicates that French-English bilinguals may have common phoneme categories for /f/ and /s/ which are similar across languages. Our study extends their conclusion to languages that are part of distinct languages families and which differ a lot in terms of phoneme inventory.

In addition, results indicate that we succeeded in inducing recalibration in our participants, since participants who had exposure toward /f/ produced more /f/ responses in the post-test than participants who had exposure toward /s/. This confirms that our stimuli were adequate to trigger lexically guided phonetic recalibration. This bilingual set of stimuli (about 300 stimuli, including 80 /f/-/s/ continua in various words or minimal pairs) can therefore be used in future experiments based on lexically guided phonetic recalibration.

Finally, there was an effect of the test language, and this effect was equivalent across groups (there was no interaction). Although we piloted our stimuli to try to find the middle of each continuum - the most ambiguous point where participants would respond half /f/ half /s/ - there was still some bias and the bias differed across languages (and even across minimal pairs). This is quite common in the literature to have a bias in the results toward one end point of the continuum and it does not affect our conclusion.

In conclusion, the present study indicates that lexically-guided phonetic recalibration may transfer across languages in French-English bilinguals although these languages are quite distant from a phonetic standpoint. It also provides a robust set of stimuli that can be used for future research in the domain of perceptual learning in bilingual speakers.

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8. REFERENCES

[1] D. Norris, J. M. McQueen, and A. Cutler, "Perceptual learning in speech," *Cogn. Psychol.*, vol. 47, no. 2, pp. 204–238, 2003.

[2] E. Reinisch, A. Weber, and H. Mitterer, "Listeners retune phoneme categories across languages.," *J. Exp. Psychol. Hum. Percept. Perform.*, vol. 39, no. 1, pp. 75–86, 2013.

[3] T. Kraljic and A. G. Samuel, "Generalization in perceptual learning for speech," *Psychon. Bull. Rev.*, vol. 13, no. 2, pp. 262–268, 2006.

[4] K. Schuhmann, "Cross-linguistic perceptual learning in advanced second language listeners," *Proc Ling Soc Amer*, vol. 1, no. Article 31, pp. 1–32, 2016.

[5] V. Marian, H. Blumfield, and M. Kaushanskaya, "The Language Experience And Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals," *J. Speech, Lang. Hear. Res.*, vol. 50, pp. 940–967, 2007.

[6] K. J. P. Woods, M. H. Siegel, J. Traer, and J. H. McDermott, "Headphone screening to facilitate web-based auditory experiments," *Attention, Perception, Psychophys.*, vol. 79, no. 7, pp. 2064–2072, 2017.

[7] T. M. Byun and M. Tiede, "Perception-production relations in later development of American English rhotics," *PLoS One*, vol. 12, no. 2, pp. 1–22, 2017.

[8] E. Keuleers and M. Brysbaert, "Wuggy: A multilingual pseudoword generator," *Behav. Res. Methods*, vol. 42, no. 3, pp. 627–633, 2010.

[9] R. Mundry and C. L. Nunn, "Stepwise model fitting and statistical inference: turning noise into signal pollution.," *Am. Nat.*, vol. 173, no. 1, pp. 119–123, 2009.

[10] T. Hothorn, F. Bretz, and P. Westfall, "Simultaneous inference in general parametric models," *Biometrical J.*, vol. 50, no. 3, pp. 346–363, 2008.