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PERCEPTION OF STRESS BY FRENCH, SPANISH, AND BILINGUAL SUBJECTS*

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ABSTRACT

Previous research has shown that French subjects, as opposed to Spanish subjects, have difficulties in distinguishing two words that differ only as far as the location of stress is concerned. In French, stress is not contrastive, and French subjects are 'deaf' to stress contrasts.

In Experiment 1, we replicate this finding with a new and more powerful paradigm for assessing the perception of stress. With this new method, we obtain a complete separation of the two subject populations. In Experiment 2, we test highly proficient French-Spanish bilinguals with the same paradigm. Our findings are that the performance of individual bilinguals is either French-like or Spanish-like. The factor that best predicts the bilingual's performance is the country in which the subject is born. Consequences for models of bilingualism are discussed.

1. INTRODUCTION

During the processing of spoken language, words are coded phonologically [1]. This representation is language-specific and limits our capacity to perceive distinct phonological properties of a foreign language, giving rise to what we call phonological 'deafnesses'. For instance, French subjects, as opposed to Spanish subjects, have difficulties in distinguishing two words that differ only as far as the location of stress is concerned, e.g. *vásuma* and *vasúma* [2]. This is due to the fact that in French, word stress predictably falls on the word's last non-schwa syllable; French speakers, therefore, do not need to code stress in their phonological representation of lexical items. In Spanish, by contrast, stress is contrastive, witness the pair *bébe* '(s/he) drinks' – *bebé* 'baby'; hence, Spanish speakers must code stress in their phonological representation of words.

An interesting question concerns the perception of stress by bilingual French-Spanish subjects. That is, these bilinguals might either have two phonological systems or one. In the former case, they should not have difficulties in perceiving stress contrasts. In the latter case, by contrast, those with the French system should have difficulties in perceiving such contrasts.

In this paper, we present an experiment aimed, firstly, at establishing a new and more powerful method for assessing the perception of stress individual by individual, and, secondly, applying this method to bilingual subjects. Specifically, in Experiment 1, we validate our paradigm with monolingual French and Spanish subjects, thus replicating the original stress 'deafness' effect; in Experiment 2, using the same paradigm, we test French-Spanish bilinguals who have been raised bilingually.

2. EXPERIMENT 1

Our new paradigm is based on the observation in Dupoux *et al*. [2] that the stress 'deafness' seems to increase as a function of memory load. We thus present subjects with increasingly longer sequences of two non-words making up a minimal pair in terms of either phonemic content or the location of stress. Subjects listen to these sequences, and have to reproduce each one of them.

2.1 Method

2.1.1 Material

Two minimal pairs were constructed, one involving a phonemic difference, i.e. /kúpi, kúti/, the other one involving a stress difference, i.e. /píki, pikí/. All items are non-words in both French and Spanish. All items were recorded about 10 times by a female speaker, a trained phonetician who tried to mimic the Spanish stress contrast. Six recordings of each word were selected. For each of the four experimental items, the pitch of the six tokens was changed by means of the psola algorithm, with the percentages 105, 103, 101, 99, 97, and 95, respectively, in order to obtain more phonetic variation.

In addition, the word 'OK' was recorded once by a male speaker. All recorded items were digitized at 16kHz at 16 bits, digitally edited and stored on a computer disk.

For each minimal pair, the first item was associated to the number key 1 and the second item was associated to the number key 2. Five experimental blocks per minimal pair were then constructed. Each experimental

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block contained eight sequences of repetitions of the two items, going from two repetitions per sequence in the first block to six repetitions per sequence in the fifth block.

The sequences were chosen as follows. There are four logically possible two-word sequences, which each appeared twice in the first block. There are eight logically possible three-word sequences, which all appeared in the second block. For the remaining three blocks, there were 16, 32, and 64 possible sequences, respectively. For each of these blocks, eight among the most varied sequences were chosen. All selected sequences are listed in the Appendix.

The overall design was 2 x 2 x 5: Language x Contrast x Sequence Length.

2.1.2 Subjects

Ten native French speakers and ten native Spanish speakers were tested individually. The French subjects, eight men and two women, were aged between 20 and 38. The Spanish subjects, two men and eight women, were aged between 23 and 29.

None of the subjects had a known hearing deficit. One additional female Spanish subject was tested and excluded from the results; in her responses, the complete reversals in either the phoneme or the stress condition outnumbered the correct responses, suggesting that she might have confused the number key associated to the first item with the one associated to the second item.

2.1.3 Procedure

Subjects were first tested on the minimal pair containing the phonemic contrast. Subjects were told that they were going to learn two words in a foreign language. They could listen to the various tokens of these two words by pressing the number keys 1 and 2, respectively. The item /kúpi/ was associated to key 1, while its counterpart /kúti/ was associated to key 2. Subjects were first asked to press the number key 1, upon which they heard all tokens of /kúpi/. They were then asked to press the number key 2, upon which they heard all tokens of /kúti/. Subsequently, subjects could continue listening to the various tokens of the two items by pressing the associated keys; pressing each one of these keys now resulted in the playing of one token of the corresponding item. They could thus hear as many tokens of the two items as they desired.

Next, it was verified that subjects had learned the distinction between the two items as well as the correct association between the items and the number keys. That is, they heard a token of one of the items and had to press the associated key, 1 or 2. A message on the screen informed subjects whether their responses were correct. The message was ‘OK!’ or ‘ERROR!’, and was displayed for 800 msec. This phase lasted until subjects had given seven correct responses in a row; moreover, these seven trials could not contain more than four tokens of the same item in a row.

During the test, subjects listened to the 40 sequences constituted by repetitions of the two items, divided into the five blocks as described in section 2.1.1. Their task was to reproduce each sequence by typing the associated keys in the correct order. For each subject, the order of the eight sequences was randomized, and each item was instantiated randomly by one of the six recorded tokens. In order to prevent subjects from mentally translating the words into the associated numbers while listening to the sequence, the silent period between the items in a sequence was kept short, i.e. 80 msec. Each trial consisted of a sequence followed by the word ‘OK’, and subjects could not begin typing their response until upon having heard this word. Subjects did not receive feedback as to whether their responses were right or wrong. However, if the length of their response sequence did not match that of the input sequence, they were informed about this and asked to enter their answer again, until a sequence of the correct length was entered. A 1500 msec pause separated each response from the next trial.

Finally, the whole procedure was repeated with the minimal pair containing a stress contrast. The item with stress on the first syllable, /píki/ was associated to key 1, while its counterpart with stress on the second syllable, /pikí/, was associated to key 2.

On average, the entire experiment lasted about 20 minutes. Responses were recorded on a computer disk.

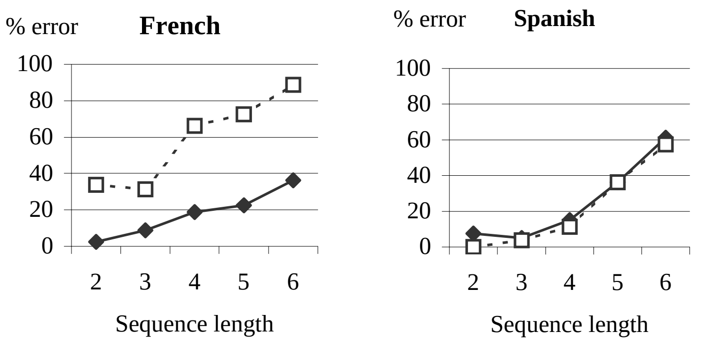
2.2 Results

Error rates as a function of sequence length for the phoneme and the stress contrast for the French and Spanish subjects are shown in Figure 1a.

These data were submitted to ANOVAs with the factors contrast (phoneme *vs*. stress) and sequence length (2 to 6). As to the French subjects, there is a main effect of contrast ($F(1,9) = 72$, $p < 0.001$), a main effect of sequence length ($F(1,9) = 32$, $p < 0.001$), and an interaction between contrast and sequence length ($F(1,9) = 5.7$, $p = 0.001$). Post-hoc comparisons indicate a significant effect for the individual sequence lengths (Bonferoni corrected p-values: 0.045, 0.035, 0.001, 0.001, and 0.001). The Spanish subjects only show a main effect of sequence length (Spanish: $F(1,9) = 48$, $p < 0.001$).

An ANOVA with the factors language, contrast and sequence length reveals a significant interaction between contrast and language ($F(1,18) = 64.8$, $p < 0.001$).

For each subject, we computed a difference score, defined by the percentage of errors in the stress condition minus the percentage of errors in the phoneme condition. The score of the French subjects ranges from 20% to 65%, while that of the Spanish subjects ranges from -15% to 7.5%. In other words, with respect to this score there is no overlap between the two populations. In a Mann Whitney test, the French and the Spanish populations differ from one another with $p < 0.001$.



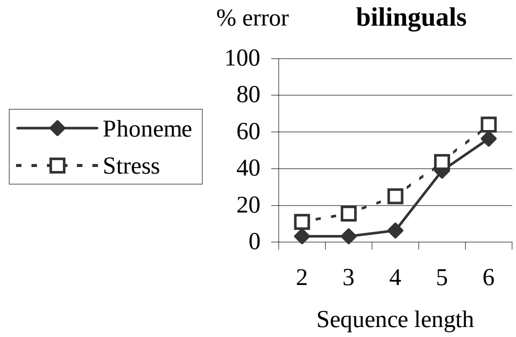


Figure 1a:
Error rates as a function of sequence length for the phoneme and the stress contrast, for 10 French and 10 Spanish subjects

Figure 1b:
Error rates as a function of sequence length for the phoneme and the stress contrast, for 8 bilingual subjects

2.3 Discussion

In this experiment, we found, firstly, that French and Spanish subjects have similar results for the phoneme condition. That is, their performances both degrade with longer sequences and they are at the same level. Secondly, in the stress condition, French subjects make about twice as many errors as Spanish subjects, the latter having a performance level equivalent to that in the phoneme condition. Interestingly, in this paradigm the stress 'deafness' effect found in French subjects is present even for the shortest sequences.

The paradigm that we constructed is very powerful, in that the distribution of responses across populations in the stress condition show no overlap. That is, based on their performance, we can classify individual subjects as either French or Spanish with 100 % accuracy. This should be compared to the results with the previous paradigm used by Dupoux *et al*. [2], where individual responses showed considerable overlap; indeed, they obtained 63% accuracy in the separation of the two populations.

3. EXPERIMENT 2

In this experiment, we test the perception of stress with the new paradigm in native French-Spanish bilinguals.

3.1 Method

3.1.1 Material and procedure

The material and procedure were identical as those in Experiment 1. Following the test, subjects filled in an extensive questionnaire concerning their linguistic background, which lasted about 25 minutes.

3.1.2 Subjects

Eight French-Spanish bilinguals, four men and four women aged between 18 and 27, were tested individually. They were born from a French-speaking mother and a Spanish-speaking father, or, *vice versa*, from a Spanish-speaking mother and a French-speaking father, and they had been raised bilingually. They had all lived in France for at least the last two years preceding the test.

None of the subjects had a known hearing deficit. One additional subject was tested and excluded from the results, due to too many complete reversals among the responses.

3.2 Results

Error rates as a function of sequence length for the phoneme and the stress contrast are shown in Figure 1b. These data were submitted to an ANOVA with the factors contrast (phoneme *vs*. stress) and sequence length (2 to 6). There is a significant effect of sequence length ($F(1,7) = 31$, $p < 0.001$), and a marginally significant effect of contrast ($F(1,7) = 4.7$, $p = 0.067$).

For each subject, we computed the difference score, defined by the percentage of errors in the stress condition minus the percentage of errors in the phoneme condition. This score ranged from –5% to 30%. The difference scores of the bilinguals, as well of those of the French and Spanish subjects tested in Experiment 1, are plotted in Figure 2.

The bilingual population differs from both the French population (Mann Whitney, $p < 0.001$) and the Spanish population ($p < 0.03$).

3.3 Discussion

As is clear from Figure 2, three bilinguals have performances corresponding to the best French subjects, while the remaining five bilinguals correspond to the Spanish subjects. This raises the question as to which factor determines whether an individual subject will show French-like performance and, hence, exhibit the stress 'deafness' effect.

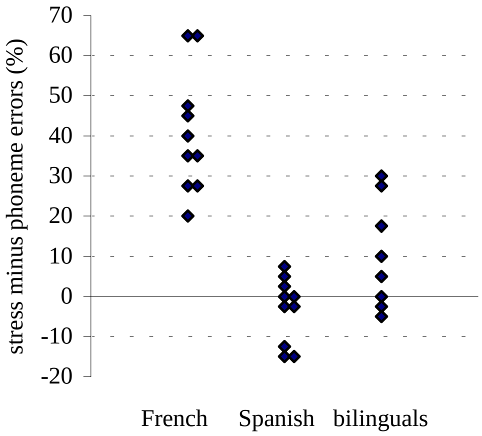


Figure 2:
Difference score for individual subjects in Experiments 1 and 2

In table 1, some of the data reported by the bilingual subjects in the questionnaire are shown. The subjects are identified by their difference score and displayed in increasing order of this score; thus, the top five have a Spanish-like performance, while the remaining three are French-like.

Difference score (%)	*Born in*	*Mother*	*Preferred language*	*Self-rated pronunciation*
-5	Spain	French	Spanish	equal
-2.5	UK	French	Spanish	best in French
0	Spain	French	Spanish	equal
5	Spain	French	Spanish	equal
10	Spain	French	French	best in French
17.5	France	French	Spanish	equal
27.5	France	Spanish	French	best in French
30	France	Spanish	Spanish	best in French

Table 1:
Subjects' background

A regression analysis based on these data reveals that the subjects' difference scores highly correlate with the country in which they are born ($R = 0.90$, $p = 0.002$).[1] There is also a high correlation between the difference score and the mother's language, but this correlation is negative ($R = -0.85$, $p < 0.008$). In other words, the difference score correlates with the father's language. This latter correlation might be due to the fact that the language of the father is highly correlated to the language in which the subjects are born. The correlations with the remaining two factors are not significant (preferred language: $R = 0.39$, $p < 0.34$; self-rated pronunciation: $R = 0.47$, $p < 0.24$).

[1] For the subject who was born in the U.K. we coded Spain, the English stress system being more similar to the Spanish one than to the French one. In fact, as in Spanish, main word stress is unpredictable in English.

4. CONCLUSION

To sum up, in Experiment 1, we have replicated the stress 'deafness' effect in a new paradigm. This paradigm is strong enough to yield individual data and 100% separation between French and Spanish subjects. In Experiment 2, we tested French-Spanish bilinguals and found that that some of them had a performance similar to that of the French subjects. Their stress 'deafness', though, did not yield the same level as that of the most extreme monolinguals.

The finding that some bilinguals exhibit stress 'deafness' is compatible with Cutler *et al*. [3,4], who reported that bilingual subjects used only one phonological system for speech segmentation. However, Cutler *et al*. found that the language preferred by the subjects best predicted which one of the two systems was used, while in our experiment, the language in which the subjects were born best correlated with their performance.

APPENDIX

two-word sequences:

11	21
12	22

three-word sequence:

111	211
112	212
121	221
122	222

four -word sequences:

1121	2111
1122	2112
1211	2122
1221	2212

five -word sequences:

11121	21112
12112	21211
12122	21221
12211	22122

six-word sequences:

112121	211221
112212	212112
121112	221212
122121	222121

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