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A Destressing "Deafness" in French?

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Spanish but not French uses accent to distinguish between words (e.g., tópo vs topó). Two populations of subjects were tested on the same materials to determine whether this difference has an impact on the perceptual capacities of listeners. In Experiment 1, using an ABX paradigm, we found that French subjects had significantly more difficulties than Spanish subjects in performing an ABX classification task based on accent. In Experiment 2, we found that Spanish subjects were unable to ignore irrelevant differences in accent in a phoneme-based ABX task, whereas French subjects had no difficulty at all. In Experiment 3, we replicated the basic French finding and found that Spanish subjects benefited from redundant accent information even when phonemic information alone was sufficient to perform the task. In our final experiment, we showed that French subjects can be made to respond to the acoustic correlates of accent; therefore their difficulty in Experiment 1 seems to be located at the level of short-term memory. The implications of these findings for language-specific processing and acquisition are discussed.

The native speaker's difficulties with some nonnative segmental contrasts is well documented (e.g., Polka & Werker, 1994). Much less is known about the way in which rhythmical and structural properties of the native language affect encoding of foreign words. This study reports four experiments that assess the claim that nonsegmental properties of the native language greatly affect the way in which unfamiliar items are processed and represented.

Learning a language requires, *inter alia,* acquiring knowledge of the language's sound pattern. Psycholinguists have generally assumed that learning the sound pattern of a native language involves learning the segments of the language. This assumption is evident in books and articles on the subject (e.g.,

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Carroll, 1960, for an early formulation of this view; Miller and Jusczyk, 1990, for a later one). There is no question that segments are an essential ingredient of the sound pattern of language, although many other properties of speech are also important. Foreign accents reflect segmental difficulties but also suprasegmental ones. For instance, informal observations suggest that French speakers who acquire English after puberty produce segments that are not prototypical of English, and prosodic output is usually deficient as well. It is not uncommon to hear French speakers fail to reduce vowels or make the wrong vowel prominent. Many mistakes are, in fact, due to the inability of native speakers of French to place stress in the correct place. How is one to explain these consistent mistakes? Why is it that even proficient French speakers of English produce anomalous prosodic structure?

In this paper we attempt to show that such informal observations as those alluded to above reflect the essential processing routines and representation structures elaborated specifically for one's native language. Cutler and Mehler (1993) and Christophe and Dupoux (in press) argue that prosody is essential during first language acquisition. When a child first learns a language, he or she extracts its rhythmical–periodical properties. Those properties facilitate language acquisition and trigger adjustments to perception and production routines that allow efficient language-specific processing. Moreover, in adults, these adjusted perception and production routines are no longer very flexible and disrupt the processing of foreign languages in certain ways. This helps us to explain how natural languages are processed differently by native and by proficient foreign speakers of those languages.

These considerations led us to conjecture that speakers of different languages become sensitized not only to different phonetic contrasts but also to different prosodic properties. If this hypothesis is correct, determining which rhythmical and prosodic structures create problems for foreign speakers should help us to understand how the native language is acquired and how foreign languages are subsequently learned.

Consider the accent differences between Spanish and French. In Spanish, the default position for accent[1] in multisyllabic words is on the penultimate syllable. However, many words have accents in other positions. Indeed, there are minimal pairs that have exactly the same segments but differ in meaning because of the accent location. For example, *bébe* (''drink'' present tense) vs *bebé* (''baby'') and *tópo* (''mole'') vs *topó* (''met'') drawn from Spanish exemplify this property (see Navarro Tomas, 1946). In French, however, the accent does not carry lexical information; there is no such contrast as *bébe* versus *bebé*. In this language, the accent is described either as being not specified lexically or as falling on the last full vowel of content words (Dell & Vergnaud, 1984).

Thus, speakers of Spanish must process and represent the accent to identify the lexical item(s) intended by the speaker. Speakers of French, however, do not need to process the accent, at least not in the same way. As far as lexical identification is concerned, only segmental content matters, and accent information could be completely left unspecified in the French lexicon.

The following experiments investigate this hypothesis by testing the ability of French and Spanish speakers either to detect stress differences (Experiments 1 and 3) or to ignore them (Experiment 2). The final experiment addresses the issue of the level at which French/Spanish differences in performance may arise.

Experiment 1

Our first study tested native speakers of French and of Spanish with an ABX discrimination task involving an accent contrast. Subjects were presented with three items that varied only in accent location and had to press a button to indicate whether the last item corresponded to the first or to the second item. In this experiment, we tested two accent con-

[1] In this paper we use the term ''accent'' to refer to phonetic/perceptual prominence in a string of syllables. We stay neutral as to whether such prominence is correlated or not with the notion of metrical stress as used in phonology.

trasts on trisyllabic CVCVCV items: *bópelo* vs *bopélo* (1st vs 2nd syllable with accent) and *bopélo* vs *bopeló* (2nd vs 3rd syllable with accent).

Note that these accent patterns are all possible in Spanish, although the penultimalte pattern (*bopélo*) may be said to be the unmarked case. Since our two experimental contrasts involve items with accents on the penultimate syllable, there is no reason to expect that, for Spanish subjects, a 1st vs 2nd syllable accent would be easier or harder than a 2nd vs 3rd. In contrast, French is a language with the accent on the last full vowel of content words. One might expect accent-final items to be perceived as natural, whereas items with nonfinal accents should be perceived as foreign-sounding. In this case, 2nd vs 3rd syllable accent involves a difference in legality and should be easier for the French than 1st vs 2nd (which are both illegal). This is not, of course, the only possibility. French subjects might assimilate all accent patterns to one, or simply not represent accent at all. In this case, both contrasts would be equally difficult.

French and Spanish differ in more than placement of accent. First, French has been described as a syllable-timed language. Spanish is a syllable-timed language, but it also involves an alternating pattern of prominence peaks that reflects a higher order prosodic unit: the foot. Nonetheless, previous psycholinguistic investigations found that the two languages processed syllabic structures in very similar ways (Bradley, Sánchez-Casas, & García-Albea, 1993; Mehler, Dommergues, Frauenfelder, & Segui, 1981; Pallier, Sebastian-Gallés, Felguera, Christophe, & Mehler, 1993; Sebastian-Gallés, Dupoux, Segui, & Mehler, 1992). Second, French has 14 vowels, and Spanish only 5. Similarily, Spanish and French differ in the consonantal inventory and in allowed consonant clusters. To cope with these differences, our materials included only a subset of segments and syllable structure legal in both languages.

The following experiments use the exact same stimuli for French and Spanish hearers. However, since recording either French or Spanish speakers might have too obviously advantaged one population over the other because of the fine difference in the phonetic realization of phonemes in the two languages, we decided to record the stimuli using speakers of a third language: Dutch. Dutch is a stress-timed language, which allows accent to appear in difference places in words. The phoneme subset that we selected for French and Spanish contains phonemes that are all pronounceable in Dutch. In an informal pretest, Dutch realization of these phonemes was judged to be slightly foreign-sounding but highly acceptable to both French and Spanish listeners.

Method

Materials. Twelve CVCVCV triplets of the form (*bópelo, bopélo, bopeló*) were constructed (see Appendix). Each member of a triplet had the same phonemic content and the main accent falling on the first, second, or third syllable. None of the vowels were reduced, and they belonged to the set [e], [i], [o], [a], [u]. All items were nonwords in both French and Spanish.

The 12 triplets were recorded by three speakers of Dutch (two females, one male) and checked by a phonetician. They were instructed to mark word accent clearly on the first, second, or third syllable while keeping the other vowels unreduced. Each item was digitized at 16 kHz at 16 bits (on an OROS AU22 A/D Board), digitally edited, and stored on a computer disk.

From the recorded experimental triplets, 96 trials were constructed. Each trial consisted of three stimuli, A, B, and X, the first two said by the two female speakers and the third by the male speaker. The A and B items always had the same segmental content but differed in accent. Two contrasts were tested: 1st vs 2nd and 2nd vs 3rd. For a given contrast, A and B received the two accents in the two possible orders (e.g., *bópelo-bopélo*, or *bopélo-bópelo*). This resulted in four different A–B combinations for each experimental triplet. The X item always had the same segmental content as A or B, but on half of the trials X had the same accent as A and on the other half it had the same accent as B. The overall design was 2 × 2 × 2: Accent-Contrast × Accent-Order × X-identity.

The 96 experimental trials were split into two blocks (with each condition and stimulus represented equally often in each block). An extra practice block of 10 trials that contained the same conditions but with different items from the experimental blocks was constructed.

Procedure. Each experimental trial presented the three stimuli (A, B, and X) separated by an interval of 500 ms. Subjects were instructed to listen to words in a foreign language. They were told that the first two stimuli were different and that the third one was identical to the first or to the second. They were required to press a button on their left or on their right to indicate whether X was identical to A or to B, respectively. Subjects were given a 4000-ms deadline to respond. The next trial started 1000 ms after each response or after the deadline.

In the 10 practice trials, subjects received feedback on whether their response was correct or not. Feedback consisted of the word ‘‘Correct’’ or ‘‘Incorrect’’ or the string ‘‘The response is A/B’’ when subjects failed to respond before the deadline. It was displayed for 1000 ms and then erased from the screen. For incorrect responses, the same trial was presented again until the response was correct. In the two experimental blocks of 48 trials, no feedback was presented. The blocks were separately randomized for each subject. A short pause separated the two experimental blocks. Responses were recorded and reaction time was measured from the onset of the X stimuli by the EXPE software package (Pallier & Dupoux, in press).

Subjects. Sixteen French and 16 Spanish subjects participated in the experiment. The French subjects were students recruited in Paris. There were 10 men and 6 women, 14 right-handers and 2 left-handers in the group. Their median age was 25. The Spanish subjects were students at the University of Barcelona and received course credit for the experiment. There were 4 men and 12 women, 13 right-handers and 3 left-handers. The median age was 20. None of the subjects understood the other language nor did they understand Dutch.

Results

One item (*vasuma*) generated many errors in this experiment and in the next and was therefore removed from subsequent analyses. Mean reaction times and error rates broken down by Language (French or Spanish), Accent Contrast (1st vs 2nd or 2nd vs 3rd), and Response Type (A or B) are displayed in Table 1. These two dependent variables were each subjected to two ANOVAs, one with subjects and one with items as random variables. Language was a between-subject factor, Response Type and Accent Contrast were within-subject factors, and all three factors were within-item.

In the errors analyses, French subjects made significantly more errors than Spanish subjects (19% vs 4%, $F1(1,30) = 17$, $p < .001$; $F2(1,10) = 158$, $p < .001$). No effect of Accent Contrast was found (F's < 1), and this factor did not interact with Language. A-responses yielded more errors than B-responses (13% vs 10%, $F1(1,30) = 4.0$, $p < .05$; $F2(1,10) = 20$, $p < .001$), but this effect was mostly due to French subjects and mostly for the accent 2nd versus 3rd contrast. The three-way interaction between Response Type, Language, and Accent Type was only significant in the subjects analysis ($F1(1,30) = 4.9$, $p < .03$; $F2(1,10) = 4.3$, $p < .1$), and the two-way interactions between Response Type and Language and between Response Type and Accent Type were only significant in the items analysis ($p < .05$). No other interaction was significant.

The reaction time analyses revealed that French subjects were slower than Spanish subjects, although the effect was significant only in the items analysis (94 ms, $F1(1,30) = 1.8$, $p > .1$; $F2(1,10) = 77$, $p < .001$). There were no effects of Accent Type. Finally, A-responses were slower than B-responses (37 ms, $F1(1,30) = 7.5$, $p < .01$; $F2(1,10) = 9.6$, $p < .01$) and there was no significant interaction with the other factors.

TABLE 1

MEAN REACTION TIME, STANDARD ERROR, AND ERROR RATE OF ABX JUDGMENTS BASED ON TWO ACCENT CONTRASTS (EXPERIMENT 1)

		Accent 1st vs 2nd (*bópelo bopélo*)			Accent 2nd vs 3rd (*bopélo bopeló*)			Mean		
Language	Response type	Mean	SE	ERR	Mean	SE	ERR	Mean	SE	ERR
French	X = A	1230	57	21%	1261	54	23%	1245	39	22%
	X = B	1226	61	19%	1228	49	14%	1227	39	16%
	Mean	1228	41	20%	1244	36	18%	1236	27	19%
Spanish	X = A	1163	52	5.1%	1178	49	3.9%	1171	35	4.5%
	X = B	1120	41	3.1%	1107	39	3.9%	1114	28	3.5%
	Mean	1142	33	4.1%	1143	31	3.9%	1142	23	4.0%

Discussion

French and Spanish subjects were asked to perform an ABX task based on two accent contrasts. Spanish subjects made very few mistakes, but French subjects had difficulty performing the task. This difference can be seen mostly in the error rate, although there was also a trend in reaction times.

Interestingly, there was no noticeable difference between the accent 1st vs 2nd contrast and the 2nd vs 3rd contrast, either for the French or for the Spanish subjects. For the Spanish, both comparisons involve accent-second items (the unmarked case) and two other accent patterns that are possible in this language. It is therefore not very surprising that the two contrasts were equally easy for the Spanish population. However, one might expect the French listeners to find the accent-final items more prototypical than the other two accent patterns. Yet there was no difference between 1st vs 2nd and 2nd vs 3rd contrasts, suggesting that the difficulty that French subjects have with accent is general.

Experiment 1 demonstrated that Spanish subjects are overall more efficient than French subjects in discriminating accent contrasts. However, it might be that the Dutch materials contained vowels or consonants that were more prototypical for the Spanish than for the French subjects. To control for these potential effects, it would be useful to reverse the previous pattern of results, that is, to find a situation that should be easy for the French to perform and difficult for the Spanish.

EXPERIMENT 2

In this experiment, we asked subjects to *ignore* accent and to respond on the basis of segmental information only. Accent was varied orthogonally with phonemic structure so that relying on accent information would lead to chance performance. The reasoning is that French subjects, who have difficulty hearing accent in the first place, would have no difficulty in ignoring it. In contrast, for the Spanish speakers, accent plays an important role in word identification. Hence, requiring Spanish subjects to ignore accent should be difficult. This experiment used the same materials as Experiment 1 and the same subject population.

Method

Materials. Twelve CVCVCV quadruplets of the form (*bópelo, bopélo, sópelo, sopélo*) were constructed (see Appendix). They resulted from the crossing of two contrasts: an accent contrast (accent in the first or accent in the second syllable) and a phoneme contrast (a single phoneme change in one of the syllables). The segmental content of the first two members of the quadruplets was the same as in Experiment 1. The phoneme change occurred equally often in the first, second, and third syllables. All items were nonwords in both French and Spanish.

The 12 quadruplets were recorded by the same three speakers of Dutch as in Experiment 1 and were digitized in the same way. From the recorded experimental quadruplets, 192 experimental trials were constructed.

Each experimental trial consisted of three stimuli, A, B, and X, the first two spoken by the two females and the third by the male. The A and B items always differed in one phoneme *and* in placement of accent. In half of the trials, A had accent first, and in the other half it had accent second. In half of the trials, A was a stimulus from the Experiment 1 set, and in the other half it was from the phoneme-change set. This resulted in 4 different A–B combinations for each experimental quadruplet (e.g., *bópelo–sopélo, bopélo–sópelo, sópelo–bopélo,* and *sopélo–bópelo*). X always had the same segmental content as A or B and had the same accent as A or B. This resulted in four different cases that we will consider as the crossing of two factors: whether X had the segments of A or B (Response Type) and whether X had an accent congruent with its segments (Congruency). As far as the latter factor is concerned, there are two cases: In one condition, X was identical to A or B in terms of both accent *and* phoneme. This was called the Accent Congruent Condition. In the other, X had the segments of one stimulus and the accent of the other. This was the Accent Incongruent Condition. The overall design was thus $4 \times 2 \times 2$: A–B combinations × Response Type × Congruency.

The 192 experimental trials were split into four blocks of 48 trials each (A, B, C, and D). Each condition and stimulus were represented equally often in each block. An extra practice block of 10 trials that contained the same conditions but with different items from the experimental blocks was constructed.

Procedure. Stimulus presentation and feedback were as in Experiment 1. Subjects were instructed to listen to words in a foreign language in which accent contrasts were irrelevant. They were told that the first two stimuli were words that differed by one speech sound and that the third one was identical to the first or to the second in terms of their speech sounds. They were required to press a button on their left or on their right to indicate whether X was identical to A or to B, respectively.

After the instructions, subjects performed the 10 practice trials, receiving feedback on whether their response was correct or not. As in Experiment 1, subjects were not allowed to progress to the experimental session unless they had correctly responded to all the items in the practice session. After the practice trials had been completed, subjects received two experimental blocks of 48 trials (half of the subjects received Blocks A and B and half received Blocks C and D) with no feedback. The blocks were separately randomized for each subject. A short pause separated the two blocks. Response deadline, intertrial interval, and reaction time measurement were as in Experiment 1.

Subjects. Sixteen French and 16 Spanish subjects participated in the experiment. They were drawn from the same population as in Experiment 1. The French subjects included 11 men and 5 women, 13 right-handers and 3 left-handers. Their median age was 22. The Spanish subjects were 2 men and 14 women, 15 right-handers and 1 left-hander. The median age was 21. None of the subjects understood the other language.

Results

As in Experiment 1, the item *vasuma* generated many errors and was removed from subsequent analyses. Reaction times and error rates were subjected to subject and item ANOVAs (see means in Table 2). Language (French or Spanish) was a between-subject factor; Response Type (A or B) and Congruency (Congruent vs Incongruent) were within-subject factors. All three factors were between items.

The error analyses revealed an effect of Language, with Spanish subjects making more errors than French subjects (11.6% vs 6.6%, $F1(1,30) = 4.0$, $p < .05$; $F2(1,10) = 17$, $p < .002$). The Incongruent Condition generated more errors than the Congruent Condition (10.9% vs 7.3%, $F1(1,30) = 7.4$, $p < .01$; $F2(1,10) = 8.7$, $p < .01$), but this was mostly due to the Spanish subjects. However, the interaction between Language and Congruency was significant only in the items analysis ($F1(1,30) = 2.4$, $p > .1$; $F2(1,10) = 6.8$ $p < .03$). A-responses generated more errors than

TABLE 2

MEAN REACTION TIME, STANDARD ERROR, AND ERROR RATE OF ABX JUDGMENTS BASED ON A PHONEMIC DIFFERENCE AS A FUNCTION OF WHETHER ACCENT WAS CONGRUENT OR INCONGRUENT WITH PHONEMIC INFORMATION (EXPERIMENT 2)

		Congruent (*bópelo sopélo bópelo*)			Incongruent (*bópelo sopélo bopélo*)			Mean		
Language	Response type	Mean	SE	Err	Mean	SE	Err	Mean	SE	Err
French	X = A	1072	69	6.5%	1062	67	8.5%	1067	47	7.5%
	X = B	1016	58	5.1%	1056	57	6.2%	1036	40	5.7%
	Mean	1044	44	5.8%	1059	43	7.4%	1051	31	6.6%
Spanish	X = A	1258	82	13.9%	1252	64	17.9%	1255	51	15.9%
	X = B	1173	57	3.7%	1233	61	11.1%	1203	42	7.4%
	Mean	1216	50	8.8%	1243	44	14.5%	1229	33	11.6%

B-responses (11.7% vs 6.5%, $F1(1,30) = 11.6$, $p < .002$; $F2(1,10) = 11.5$, $p < .007$), although this was mostly due to Spanish subjects. The interaction between Response Type and Language was significant in both analyses ($F1(1,30) = 4.8$, $p < .04$; $F2(1,10) = 10.0$, $p < .01$). No other interaction reached significance.

The reaction time analyses showed that Spanish subjects had significantly longer reaction times than French subjects (178 ms, $F1(1,30) = 4.1$, $p < .05$; $F2(1,10) = 59$, $p < .001$). Congruent responses did not differ from Incongruent responses ($p > .1$). A-responses yielded slower reaction times than B-responses (41 ms, $F1(1,30) = 4.2$, $p < .05$; $F2(1,10) = 6.2$, $p < .03$). There was an interaction between Congruency and Response type that was significant only in the items analysis ($F1(1,30) = 3.8$, $.05 < p < .1$; $F2(1,10) = 5.7$, $p < .04$), and no other interaction was significant.

DISCUSSION

We found that French subjects were both faster and more accurate than Spanish subjects, reversing the pattern observed in Experiment 1. This suggests that the French can concentrate on the segments and ignore irrelevant variations in accent. In contrast, Spanish subjects were slower and made significantly more errors, suggesting that they cannot ignore irrelevant accent variations. Although the Spanish listeners made more errors in the Incongruent than in the Congruent condition, the effect was not reflected in reaction times, suggesting that ignoring accent was difficult for the subjects and globally increased their reaction times.

Figure 1 shows the overall results of Experiments 1 and 2. An overall ANOVA reveals a significant interaction between tasks and Language for both Reaction Times ($p < .02$ in both items and subjects analyses) and errors ($p < .001$ in both items and subjects analyses), confirming that subjects of the two languages process phoneme and accent information in a very different way.

EXPERIMENT 3

In the previous two experiments, we compared French and Spanish subjects on ABX tasks that focused either on the accent or on the phoneme. We found that French listeners had difficulties responding on the basis of accent whereas the Spanish listeners had trouble ignoring accent. However, these differences all rest on comparisons between groups of subjects drawn from similar but different populations (students in Paris vs students in Barcelona). Another shortcoming of the previous experiments is that the differences found might be due to the way in which subjects understood the task, rather than to the way in which they perceived the stimuli. This is especially true in Experiment 2, where subjects were asked to ignore accent. French and Spanish subjects may differ in their understanding of the notion of accent.

To evaluate these possibilities, we carried out a further experiment comparing directly for each individual subject responses based on accent and responses based on phonemes, while keeping the other dimension constant. We predicted that unlike Spanish subjects, French subjects would have greater difficulty in discriminating accent compared to phonemes. We also included a *redundant* condition in which both accent and phoneme information were associated with the same response. Because Spanish subjects represent both phonemic and accent information, they should be faster in the redundant condition than in either the phoneme condition or the accent condition. French subjects, in contrast, should respond in the redundant condition as

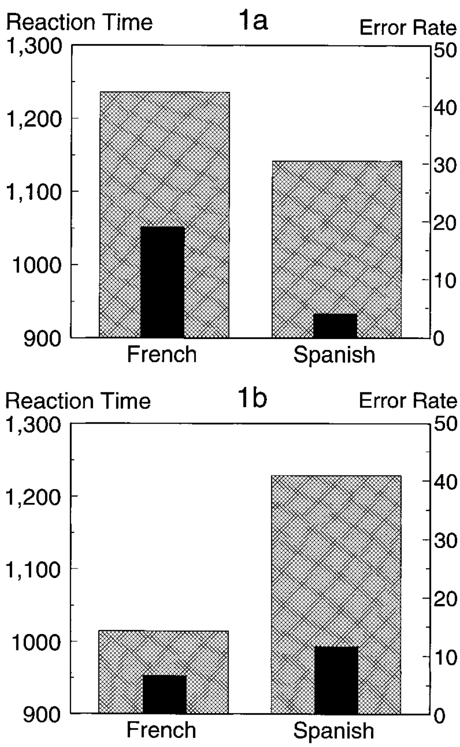

FIG. 1. Reaction times (in gray) and error rates (in black) of ABX judgments in French and Spanish subjects: (a) ABX on accent only; phonemes fixed (Experiment 1). (b) ABX on phonemes only; accent varied orthogonally (Experiment 2).

if accent were unchanged. Because of the higher number of conditions in this experiment, and because we found no differences between 1st vs 2nd accent locations in the previous experiments, we decided to limit ourselves to only these two positions.

Method

Materials. Twelve new CVCVCV quadruplets of the form (*fídape, fidápe, lídape, lidápe*) were constructed (see Appendix). They resulted from the crossing of two contrasts: an accent contrast (accent in the first or accent in the second syllable) and a phoneme contrast (a single phoneme change in one of the syllables). The phoneme change occurred equally often in the first, second, and third syllables. The vowel set was [a], [e], [i], [o], [u] and the consonant set [p], [t], [k], [b], [d], [g], [f], [s], [l], [m], [n], which are all common segments in Spanish, French, and Dutch. All items were nonwords, both in French and in Spanish. The 12 quadruplets were recorded by two speakers of Dutch (one male, one female) and were digitized as in Experiments 1 and 2.

From the recorded experimental quadruplets, 288 experimental trials were constructed. Each experimental trial consisted of three stimuli: A, B, and X. A and B were spoken by the same female speaker and the X stimulus by the male speaker. A and B differed by one phoneme only (*fídape, lídape:* Phoneme Condition), by accent only (*fídape, fidápe:* Accent Condition), or by both accent and phoneme (*fídape, lidápe:* Redundant Condition). The trials were counterbalanced such that all members of a quadruplet (*fídape, fidápe, lídape, lidápe*) appeared in both positions A and B for each of the above-defined matching conditions. This resulted in 12 different A–B combinations for each experimental quadruplet. X was identical (both in accent and in phoneme) to either A or B. There were two response types (A-responses trials and B-responses trials). The overall design was thus $3 \times 4 \times 2$: Matching Condition $\times$ Quadruplet Counterbalancing $\times$ Response Type.

The 288 experimental trials were split into four blocks of 72 trials each (A, B, C, and D). Each condition and stimulus were represented equally often in each block. A practice block of 10 trials that contained the same conditions but with different items as the experimental blocks was constructed.

Procedure. The scheduling of practice and experimental trials was as in Experiments 1 and 2. Subjects were instructed to listen to words in a foreign language. They were told that the first two stimuli were different words and that the third was identical to the first or to the second. They were required to press a button on their left or on their right to indicate whether X was identical to A or to B, respectively.

In the 10 practice trials, subjects received feedback on whether their response was correct. For incorrect responses, the same trial was immediately presented again until the response was correct. After practice, subjects received two experimental blocks of 72 trials (half of the subjects received Blocks A and B and half received Blocks C and D) with no feedback. The blocks were separately randomized for each subject. A short pause separated the two blocks. Responses were recorded and reaction times measured from the onset of the X stimuli by the EXPE software package.

Subjects. Twenty French and 20 Spanish subjects participated in the experiment. The French subjects were students from the Ecole Polytechnique, Palaiseau. There were 15 men and 1 woman, 11 right-handers and 5 left-handers. Their median age was 22. The Spanish subjects were psychology students at the University of Barcelona and received course credit for their participation. There were 3 men and 13 women, 15 right-handers and 1 left-hander, with a median age of 20. About half of the French subjects had learned Spanish as a third language (the second one being English) at the age of 14. None of the Spanish subjects had learned French. None of the subjects knew Dutch.

Results

Reaction times and error rates were subjected to subject and item ANOVAs (see means in Table 3). Language (French or Spanish) was a between-subject factor; Response Type (A or B) and Matching Condition (Phoneme, Accent, and Redundant) were within-subject factors. All three factors were within-item.

The two populations did not differ in their mean error rate (all p's $> .1$). However, there was a main effect of Matching Condition ($F1(2,76) = 21$, $p < .001$; $F2(2,22) = 17$, $p < .001$) as well as an interaction with Language $F1(2,76) = 5.3$, $p < .007$; $F2(2,22) = 7.0$, $p < .004$). The Accent Condition yielded more errors than the Phoneme Condition, especially for the French subjects (10.8% vs 2.7%, both $p < .001$) and to a lesser extent for the Spanish subjects (8.3% vs 5.6%, $p < .05$). The Phoneme and Redundant Conditions did not differ in terms of error rates. A-responses yielded more errors than B-responses (13.8% vs 5.3%, $F1(1,38) = 11.6$, $p < .002$; $F2(1,11) = 16.2$, $p < .002$) and Response Type interacted both with Language ($F1(1,38) = 4.9$, $p < .03$; $F2(1,11) = 20$, $p < .001$) and with Matching Condition ($F1(2,76) = 10.5$, $p < .001$; $F2(2,22) = 4.9$, $p < .01$). No other interaction was significant.

Overall, Spanish subjects had significantly faster reaction times than French subjects (191 ms, $F1(1,38) = 4.8$, $p < .03$; $F2(1,11) = 169$, $p < .001$). The Matching Condition factor was significant ($F1(2,76) = 27$, $p < .001$; $F2(2,22) = 15$, $p < .001$), as was an interaction with Language ($F1(2,76) = 10$, $p < .001$; $F2(2,22) = 25$, $p < .001$). To understand the interaction, we ran a series of post hoc F tests. The Accent Condition was significantly slower than the Phoneme Condition for French listeners (146 ms, $p < .001$ both by items and by subjects) but not for Spanish listeners (both p's $> .1$). In contrast, the Redundant Condition was significantly faster than the Phoneme Condition for Spanish (49 ms, $p < .05$ by subjects and $p < .02$ by items) but not for French listeners (p's $> .1$). A-responses were significantly slower than B-responses (108 ms, $F1(1,38) = 25$, $p < .001$; $F2(1,11) = 34$, $p < .001$). The Response Type factor interacted with the Matching Condition ($F1(2,76) = 12$, $p < .001$; $F2(2,22) = 6.0$, $p < .01$), and there was a three-way interaction between Response Type, Matching Condition, and Language

TABLE 3

MEAN REACTION TIME, STANDARD ERROR, AND ERROR RATE TO ABX JUDGMENTS IN A REDUNDANT, PHONEME ONLY AND ACCENT ONLY CONDITION (EXPERIMENT 3)

		Redundant (*fídape lidápe fídape*)			Phoneme (*fídape lídape fídape*)			Accent (*fídape fidápe fídape*)		
Lang	Response type	Mean	SE	Err	Mean	SE	Err	Mean	SE	Err
French	X = A	1005	41	2.7%	1019	44	2.1%	1234	54	13.7%
	X = B	1004	47	2.9%	1023	39	3.3%	1099	51	7.9%
	Mean	1005	31	2.8%	1021	29	2.7%	1167	38	10.8%
Spanish	X = A	958	36	7.9%	965	31	8.1%	1017	36	13.9%
	X = B	874	30	3.5%	965	30	3.1%	935	32	2.7%
	Mean	916	24	5.7%	965	21	5.6%	976	24	8.3%

($F1(2,76) = 4.6$, $p < .01$; $F2(2,22) = 3.5$, $p < .05$). These interactions can be accounted for by the fact that the difference between accent and phoneme is much larger in A-responses than in B-responses (and mostly due to the French listeners). Also, the difference between the Redundant and Phoneme Conditions is larger in B-responses than in A-responses (and mostly due to the Spanish listeners).

Discussion

In this experiment, French subjects were slow in the Accent Condition and relatively fast in the other two conditions. The error data corroborate the pattern observed in the response latencies. Spanish subjects were fastest in the Redundant Condition and equally slow in the Accent and in the Phoneme Conditions.

This pattern of data supports our hypothesis. French subjects have difficulty in perceiving accent and so do not use accent in the Redundant Condition. Consequently, their performances are identical in the Phoneme and in the Redundant Condition. Spanish subjects, in contrast, perceive both accent information and phonemic information with equal ease. These two conditions therefore show similar reaction times and errors. When accentual and phonemic information are redundant, Spanish subjects are faster.[2]

Notice that in the present experiment the accent condition produces errors in French listeners (10%), but relatively less so than in Experiment 1 (20%). One possible reason for this is that only one accent contrast was used in the present experiment, whereas Experiment 1 used two contrasts: 1st vs 2nd and 2nd vs 3rd. Having to deal with only one accent contrast may allow French subjects to focus more successfully on the acoustic information necessary to perform the task. The other possibility is that we used only two voices in the present experiment, thereby allowing subjects to compare A and B stimuli in terms of rather low-level characteristics (since they were spoken in the same voice). In Experiment 1, in contrast, all three stimuli were spoken in different voices, thereby inducing subjects to use a more abstract level of representation. This predicts that if we were to use only one speaker, French subjects might use low-level representations and have even less trouble with accent contrasts. We examine this possibility in the next experiment.

In the first three experiments, we consistently found differences according to Response Type. Overall, A-responses were more difficult than B-responses. This may reflect the fact that judging immediate identity (B-responses) may be performed on a shallow

[2] Note that the redundancy gain is only apparent in the reaction times, not in the errors. This could be because there is some trial-to-trial variation as to whether the phonemic information is available earlier or later than the accent information. If in congruent trials subjects use the first available information, they will then be faster on average than when they can only use one type of information. However, accuracy will not be affected.

memory store, whereas judging identity when there is some intervening material (A-responses) requires holding several stimuli in memory and keeping track of the order of each stimulus. Overall, A-response situations may be more confusing and open to different strategies than B-response situations.

Apart from this general effect, response type interacts with the matching conditions in interesting ways. In particular, the difficulty that French subjects have with accent (relative to some baseline) is always larger in A-responses than in B-responses (Experiments 1 and 3). One possible explanation for this is that as the task gets harder, existing differences in difficulty are amplified. Even in B-responses, the French subjects have difficulty with accent. One other possible explanation is that for the French subjects, accent information is mostly represented in some acoustic store, which decays rather quickly and is poorly represented or not represented at all in a more abstract and longer term storage. In B-response situations, French subjects can judge accent identity based on this low-level store. In A-response situations, the strategy would be less probable.

This raises the issue of the level at which the French deficit should be located. Is it the case that French subjects are impaired in hearing the acoustic correlates of accent, or do they not code accent in some short-term memory buffer? The next experiment was designed to examine this question.

EXPERIMENT 4

The results obtained so far suggest that French subjects have difficulty with accent. However, we do not know at which level this difficulty arises. Is it the case that French subjects have lost perceptual sensitivity to accent contrast or that they have trouble representing and storing in working memory accent patterns that are otherwise accurately perceived? To explore this issue, we placed French subjects in a simplified situation in which they only had to discriminate between two stimuli that were spoken by the same speaker. Subjects heard two stimuli (separated by a tone of varying duration) and had to judge whether the stimuli were the same tokens or varied in their pronunciation. There were two Different conditions, one in which the stimuli differed in accent (*fídape, fidápe*) and one in which they differed in one phoneme (*fídape, lídape*). In the Same condition, subjects heard two different recordings of the same stimuli.

To assess the potential effect of memory load, a pure 2-kHz tone of either 200 or 2200 ms was inserted between each member of a stimulus pair. The idea is that for long intervening tones, echoic/acoustic memory traces of the first stimulus in a pair should be less accessible than those for short tones, forcing subjects to rely on a more central representation. If French subjects are impaired in the early processing of the acoustic correlates of accent, they should have problems with the Accent Condition (compared with the Phoneme Condition), irrespective of tone duration. However, if the problem is linked to later processing/encoding stages, one would not expect to see any problem with accent in this simplified task, or only in the long-tone condition.

Method

Materials. The 12 experimental quadruplets of Experiment 3 were used and 288 new experimental trials were constructed. Each experimental trial consisted of two stimuli, A and X, which were spoken by the same Dutch female as in Experiment 3. A and X were identical in accent and phoneme (although they were different tokens, *fídape, fídape*), differed by one phoneme only (*fídape, lídape:* Phoneme Condition), or differed by accent only (*fídape, fidápe:* Accent Condition). The trials were counterbalanced so that all members of a quadruplet (*fídape, fidápe, lídape, lidápe*) appeared in position A for each of the above-defined matching conditions. This resulted in 12 different A–X combinations for each experimental quadruplet. Each A–X combination could appear in two ISI conditions, separated by a 200-ms 2-kHz intervening pure tone or a 2200-ms 2-kHz pure tone. The overall design was thus $3 \times 4 \times 2$: Matching Condition $\times$ Quadruplet Counterbalancing $\times$ ISI.

The 288 experimental trials were split into four blocks of 72 trials each (A, B, C, and D). Each condition and stimulus were represented equally often in each block, except that blocks A and C had only short ISI conditions and blocks B and D had only long ISI conditions. A practice block of 10 trials that contained the same conditions as the experimental blocks but with different items was constructed.

Procedure. Each experimental trial consisted of the following sequence of three events: stimulus A, tone, stimulus B, each separated by an interval of 300 ms. Subjects were instructed to listen to words in a foreign language separated by a tone. They were told that the two words were either identical or pronounced in a different way. They were required to press a button on their right or on their left to indicate whether X was identical to or different from A, respectively. The deadline and intertrial intervals were the same as in the previous experiments.

In the 10 practice trials, subjects received feedback on whether their response was correct or not. For incorrect responses, the same trial was presented immediately again, until the response was correct. After practice, subjects received two experimental blocks of 72 trials with no feedback presented (half received Blocks A and B and half received Blocks C and D). The blocks were separately randomized for each individual subject. Subjects were distributed into two groups according to whether they received the short ISI or the long ISI first (orders A–B and C–D for short ISI first and B–A and D–C for long ISI first). A short pause separated the two blocks. Responses were recorded and reaction times measured from the onset of the X stimuli by the EXPE software package.

Subjects. Twenty French students recruited in Paris participated in the experiment. There were 10 women and 10 men in the group. Their median age was 30. None of the French subjects had learned Spanish as a foreign language or knew Dutch.

Results

Table 4 shows reaction times and error rates on Same and Different responses across the different conditions. We analyzed the Different responses, with ISI and Matching Condition as within subject factors and Group as a between-subject factor. All three factors were within-item.

In the error analysis, there was no main effect but there was an interaction between condition and ISI in the items analysis ($F1(1,19) = 2.5$, $p > .1$; $F2(1,11) = 10.3$, $p < .008$). This interaction was due to the fact that in the long ISI condition, the Accent Condition tended to generate more errors than the Phoneme Condition (4.3% vs 1.7%, $F1(1,19) = 1.4$, $p > .1$; $F2(1,11) = 17.4$, $p < .002$), whereas no such trend was found in the short ISI condition (2.1% vs 2.7%, ns).

Reaction times in the Accent Condition were not significantly different from those in the Phoneme Condition ($F1(1,19) = 1$, $p > .1$; $F2(1,11) < 1$). Long ISIs resulted in longer reaction times than short ISIs but this difference was only significant in the items analysis (41 ms, $F1(1,19) = 2.6$, $p > .1$; $F2(1,11) = 25.2$, $p < .001$). The two factors did not interact ($p > .1$).

Discussion

In this experiment, we had subjects perform an AX discrimination task on either accent or phoneme contrasts. The results show that French subjects *can* discriminate stimuli that differ only in accent, and do so with few errors (3.2%) compared with what we found in Experiments 1 and 3 (19 and 11%). The performance was similar for accent or phoneme contrasts and remained accurate when the two stimuli were separated by a 2200-ms tone, although there was a trend toward more errors for accent contrasts in the long-tone condition. This suggests that French subjects can detect the acoustic correlates of accent and maintain a working memory of these correlates for more than 2 s. In this simplified paradigm, French subjects have very accurate access to the acoustic correlates of accent contrasts.

We can offer two reasons that the accent distinction may have been easier in the present paradigm than in Experiments 1, 2, and 3. One reason is that the present AX paradigm only involves two stimuli (the tone being ignored),

TABLE 4

MEAN REACTION TIME, STANDARD ERROR, AND RATE OF ACOUSTIC SAME-DIFFERENT AX JUDGMENTS IN AN IDENTITY, PHONEME CHANGE, AND ACCENT CHANGE CONDITION (EXPERIMENT 4)

	Short ISI			Long ISI		
Condition	Mean	SE	Err	Mean	SE	Err
			''Same'' responses			
Identity condition (*fídape fídape*)	943	29	5.4%	972	32	5.2%
			''Different'' responses			
Phoneme change (*fídape lídape*)	919	27	2.7%	942	32	1.7%
Accent change (*fídape fidápe*)	918	30	2.1%	978	42	4.3%

which decreases the memory load compared with the ABX paradigm. Subjects may only have used some kind of immediate buffer[3] rather than having to store the identity and sequential order of three trisyllabic items (which is almost a supraspan situation in terms of number of syllables). The other reason may be that the present situation involved no change in talker, allowing the task to be performed at a less abstract level than in the previous two experiments. Hence, subjects might now use an acoustic representation to discriminate accent, a strategy less available when there was a speaker change.

Both accounts converge on the same idea. We suggest that acoustic information is processed in basically the same way in French and Spanish subjects. However, to retain such information in a short-term memory store, this information must be recoded into a more abstract level. We further suggest that language specificity comes into play at this level. After acoustic information is processed, it is recoded in a different linguistic format by speakers of different languages. Word accent plays no lexical role in French and is hence not represented at this level. Why this should be so will be discussed below.

[3] Note, however, that any such immediate buffer seems to be not affected at all by an intervening 2200-ms tone.

GENERAL DISCUSSION

In this study, we have documented the poor ability of French speakers to deal with contrasts in accent. French subjects, unlike Spanish subjects, have difficulty in making discriminations based on accent as indicated by slow reaction times and numerous errors (Experiment 1). This deficiency is coupled with the absence of any beneficiary or detrimental effect of concomitant accent variations when they perform judgments based on phonemes (Experiments 2 and 4). In contrast, Spanish subjects readily discriminate among accent patterns (Experiment 1). Moreover, they can be shown to extract and represent such information automatically, even when they are asked to focus on segmental information. Orthogonal variations of accent slow them down when they have to perform a task based on phonemes only (Experiment 2). *Mutatis mutandis,* Spanish subjects respond faster when accent and phonemes are redundantly varied compared with cases when only one dimension is available for decision (Experiment 3). For Spanish subjects, accent appears to be a nondetachable aspect of phonological information, whereas for the French, this information is not represented, at least not at the level that is supposedly tapped by this task. Stress is probably used at a different level by French speakers, for example, for finding word or phonological phrase boundaries. This would be compatible with claims made by Frasier (1987) and Church (1987) that noncontrastive/allophonic information is used to parse speech into phonological constituents. Our final study shows, however, that French subjects are not altogether insensitive to differences in lexical stress in that, under appropriate circumstances, they can detect the acoustic correlates of accent (Experiment 4).

This research sheds new light on past studies of language-specific processing. Languages are often characterized by the set of phonemes that they use to distinguish words. For example, English uses the contrast between [r] and [l] (*race* versus *lace*), whereas Japanese does not. These differences affect the ability of adults and young infants to distinguish speech sounds (Best, McRoberts, & Nomathemba, 1988; Goto, 1971; Mann, 1986; Miyawaki et al., 1981; Werker & Tees, 1984a). Similarily, languages are characterized by higher order units (such as syllables, or morae) which allow the specification of restrictions on the co-occurrence of individual segments. Evidence for cross-linguistic variation in the way these structures are used in perception has been found (Bradley et al., 1993; Cutler, Mehler, Norris, & Segui, 1983; Cutler & Norris, 1988; Mehler, Segui, & Frauenfelder, 1981; Otake, Hatano, Cutler, & Mehler, 1993; Pallier et al., 1993; Sebastian-Gallés et al., 1992; Zwitserlood, Schriefers, Lahiri, & Donselaar, 1993).

Our study shows that language-specific effects are not restricted to differences in the segmental inventory (or in the inventory of higher order units). Suprasegmental information, such as accent, is also treated in different ways by listeners of different languages.[4] We believe it is likely that our results will generalize to other accent distributions. For instance, we predict that listeners who speak languages with fixed initial accent will behave like French listeners. We also predict that our results will extend to other dimensions (tone, pitch accent, etc).

Current models have viewed speech perception as consisting essentially of the discovery of phonemes arranged in their sequential order (McClelland & Elman, 1986; Norris, 1994). Although suprasegmental information was never explicitly excluded from these models, studies dealing with segments are much more common. On the basis of the above-reported studies we are inclined to favor a view according to which segmental information should be complemented with a variety of abstract representations of prosodic dimensions. Moreover, the way in which these dimensions are represented is not universal. Depending on the language’s phonology, dimensions that have a contrastive value will be specified in full detail, and others that have a fixed or predictable distribution will not be represented at all. Such a view is compatible with studies showing that knowledge about the use of suprasegmental structure in the native language begins to be acquired very early by the young infant, perhaps earlier than knowledge about permissible segmental units (Jusczyk, Cutler, & Redanz, 1993; Mehler et al., 1988; Mehler, Bertoncini, Dupoux, & Pallier, 1994).

Eimas and his colleagues have published a number of experiments that show that shortly after birth infants can discriminate contrasts that are used in a natural language (Eimas, Miller, & Juszcyk, 1987). Werker and her colleages pursued this line of work and demonstrated that before the end of their first year infants begin to neglect some contrasts absent from the language they are mastering (for instance, Polka & Werker, 1994; Werker & Tees, 1984, but some contrasts remain; see Best, McRoberts, & Sithole, 1988). Jusczyk, Friederici, Wessels, Svenkerud, and Jusczyk (1993) found that infants show some sensitivity to their language’s phonotactic properties around the age of 9 months. Notice, however, that Kuhl and her colleagues (Kuhl, 1991) have shown that the vowels are learned around 6 months, that is, a few months prior to the consonants.

[4] Cutler and Norris (1988) found that the distribution of stress plays a role in word segmentation in English. However, they claim that this effect is not really suprasegmental since it rests on a contrast between reduced and nonreduced vowels, a segmental distinction. In English, it is uncertain whether purely suprasegmental properties affect word recognition (see Cutler & Clifton, 1984).

Mehler and colleagues have argued that infants learn about the prosody much before they learn about the segments of their own language. Indeed, Mehler et al. (1988) have shown that very young infants react differentially to novel sentences from their native language very shortly after birth. Moreover, infants still display such a differential reaction when the utterances are filtered to ensure that most of the segmental information is removed and only the prosodic information remains available. Moon, Cooper, & Fifer (1993) report similar results. Thus, infants individuate prosodic properties of their native language before they begin to specify its segmental aspects. Incidentally, it can be argued that the early individuation of prosodic properties protects the infant who is confronted from birth by multilingual input. Jusczyk et al. (1992) have shown that infants around 6 months are sensitive to sentence-level prosodic boundaries. Jusczyk et al. (1993) found that by 6 months English infants start to be sensitive to the typical stress pattern of their language (that is, strong–weak). We conjecture that around the same age, French infants should start losing sensitivity to accent contrasts.

Although much remains to be done, we believe that prosodic information will be added to our current models of adult speech perception and improve our understanding of how speech is acquired and used by human infants.

APPENDIX: MATERIALS

Experiment 1

baveta, bopelo, detoma, lumisa, mepado, metilo, picadu, povami, rimato, someta, tamido, vasuma.

Experiment 2

bopelo–sopelo, povami–lovami, tamido–pamido, vasuma–fasuma, detoma–deboma, lumisa–ludisa, picadu–piradu, rimato–ripato, mepado–mepato, metilo–metibo, someta–somefa, baveta–baveka.

Experiments 3 and 4

bedapi–nedapi, kidosa–kimosa, dabitu–dalitu, nelufo–nepufo, dufoga–dufola, nibako–tibako, fidape–lidape, nolaku–nosaku, fubeno–fubeto, poleda–poleka, kebuli–pebuli, tamido–tamipo.

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