Perceptual Evidence for Separate Processing of Stress Pattern and Phonemic String

Valérie Pasdeloup, José Morais and Régine Kolinsky
Laboratoire de Psychologie Expérimentale, Université Libre de Bruxelles,
117 av. Adolphe Buyl, 1050 Brussels, Belgium

ABSTRACT

In order to determine if lexical stress pattern and phonemic string are represented separately at some level of processing, a target word recognition task was used under dichotic listening presentation. Two stimuli were presented simultaneously, one to one ear and one to the other ear. The stimuli are constructed in such a way that, if listeners combine the phonemic string from the stimulus presented to one ear with the stress pattern from the stimulus presented to the other ear, they experience the illusory perception of a word which corresponds to the prespecified target. The results suggest that stress pattern and segmental string can be represented separately at least at a prelexical level.

INTRODUCTION

In nonlinear phonological theories (metrical and autosegmental), suprasegmentals are independent of the segmental strings to which they are associated. In the present experiment, we investigated whether in Portuguese, a lexical-stress language, the stress pattern and the phonemic string are represented separately at some processing level. We used a target detection task under dichotic listening presentation (two different stimuli are presented simultaneously, one to one ear and one to the other ear). We hypothezed that stress pattern can be analyzed separately of phonemic string. We predicted that an illusory word could be obtained by combining the phonemic string from the stimulus presented to one ear with the stress pattern from the stimulus presented simultaneously to the other ear. In Portuguese, stress syllables have a full vowel, a longer duration, and a stronger intensity while most unstressed syllables have a reduced vowel, a shorter duration, and a weaker intensity. Still, in formal register or when intrinsically heavy, vowels may not be reduced when unstressed. Since we wanted stress contrasts to be expressed only in the prosodic dimension, we chose a set of items whose vowels are not reduced when unstressed.

EXPERIMENT

The purpose of this perceptual experiment is to establish if subjects can experience in a dichotic listening situation the illusion of hearing a word, although its phonemic information is given to one ear and its lexical stress information to the other ear. Let us take the Portuguese word *MINgua* (upper case will be used to represent a stressed syllable). It shares the phonemic constituents (but not the stress pattern) with the word *minGUa* presented to one ear, and the stress pattern (but not the phonemic string) with the word *VIcio* presented to the other ear. If, when presented with the dichotic pair minGUa-VIcio (called experimental (E) trial), subjects experience sometimes the illusion of hearing the target *MINgua*, it could support the hypothesis that phonemic string and stress pattern are processed separately and recombined erroneously.

Of course, not all false detections (FDs) of the target MINgua observed in this E trial could safely be attributed to such a false recombination. The listener could interpret incorrectly the stress of minGUa, which shared the segmental string with the target MINgua. Consequently, we designed a control (C) trial where none of the items presented dichotically has the stress pattern of the target: the target word *MINgua* shares the phonemic constituents with the word *minGUa* presented to one ear (as in the E trial), but does not share the stress pattern with the word *viCIo* presented to the other ear. In order to establish the occurrence of false recombinations, FDs of the target MINgua in E trials should be higher than Fds of this target in C trials. In addition to the E and C trials described above which are target-absent trials, two target-present trials were designed. E and C trials obeyed the same rule in both target-absent and target-present situations (cf. Table 1).

Table 1. *Set of trials for the target word MINgua*

	Experimental trial	Control trial
Target-absent	minGUa - VIcio	minGUa - viCIo
Target-present	MINgua - VIcio	MINgua - viCIo

Method

Materials. We chose bi- and trisyllabic stress-pairs which differ only in the position of lexical stress, on the first or second syllable. Four groups of stimuli were built, each containing four word targets, presented with their corresponding set of stimuli. The four groups are defined as follows: (1) pairs of trisyllabic word stimuli which do not share any phoneme (as in VIcio-minGUa), (2) pairs of bisyllabic word stimuli which share the second syllable (as in CANsam-PENsam), (3) pairs of trisyllabic pseudoword stimuli which do not share any phoneme (as in siRIo-VINgua), (4) pairs of bisyllabic pseudoword stimuli which share the second vowel (as in FUNçam-VENgam). The pairs of stimuli sharing phoneme are called stimuli S and those which do not share any phoneme NS. Sixteen stress-pairs consisting of words (W), pseudowords (PW), or both W and PW were selected in order to build the trials for these four groups. W and PW were recorded by a native male speaker of Portugal. In order to synchronize, for each pair, the dichotic stimuli onset and offset, we used a speech compression algorithm (from Digidesign's Sound Tool II). Synchronization was made on the basis of the average duration of dichotic stimuli.

Subjects. Fourteen native speakers of Portugal from University of Lisbon took part in the experiment.

Procedure. Subjects were tested individually and heard the dichotic stimuli over headphones. They were instructed to listen carefully to each pair and to respond if the target word written in a booklet has been presented or not. They heard a pair of stimuli every 3 seconds. Half of subjects received the W stimuli trials in a first session and the PW stimuli trials in a second one; the other half received them in the reverse order. Each target-absent trial corresponding to one target word was presented six times and each target-present trial two times. Trials were presented in a pseudo-random way. Each session was preceded by a training phase of 16 trials. Items of each type of pair were counterbalanced for ear assignment.

RESULTS

Results for target-absent trials (see Table 2)

In order to evaluate the false recombination of stress pattern and segmental string, an illusion rate was calculated by dividing the number of Fds on E trials by the total sum of Fds on E and C trials. A rate superior to 0.5 signals the occurrence of false recombination. The mean percentage of Fds is higher in the E than in the C

trial. Thus, subjects more often get the illusion of hearing the target word when it shares its stress pattern with one of the stimulus of the pair than when it does not. The illusion rate is higher than 0.5 in all groups, except for the group of W NS stimuli which share no phoneme. Moreover, it seems that sharing phonemic units strongly favours the recombination phenomenon within the groups of W stimuli, whereas no such effect is apparent for the groups of PW stimuli.

Variance analyses (Trial [E vs. C] X Group of stimuli) by subjects and by target word were conducted. The analyses revealed highly significant effects of Trial ($p < .0005$) and Group ($p < .0005$ and $p < .025$, respectively). The interaction is also significant ($p < .0005$ and $p < .01$, respectively). Trial is not significant for the W NS stimuli, but is highly significant for the W S stimuli sharing the second syllable ($p < .0005$ and $p < .0005$, respectively). Trial is significant for both groups of PW stimuli, but only in by-subjects ($p < .01$ and $p < .005$, for NS and S, respectively). The suggestions that can be drawn are the following: first, stress pattern and segmental string can recombine erroneously, and second, this recombination may depend on both lexicality of the stimuli and the fact that they share or not phonemic units.

Table 2. *Percentages of false detections and illusion rates for target-absent trials*

Stimuli	Experimental trial	Control trial	Illusion rate
Word NS	25.1%	23.2%	0.519
Word S	54.2%	25.9%	0.677
Pseudoword NS	30.1%	21.4%	0.584
Pseudoword S	57.4%	43.2%	0.571
Mean	41.7%	28.4%	0.595

Results for target-present trials (see Table 3)

Subjects correctly detect the target word when it is present in the trial. The rate of correct detections is slightly higher in the E trial, especially in the groups of PW stimuli. In these trials, the distractor (i. e., the stimulus paired with the target) shares the stress pattern with the target, whereas it does not in the C trials. Thus, the detection of the target word was presumably facilitated when it was paired with a stimulus that carried the same stress pattern. These results could be interpreted as a "stress sharing advantage"; the so-called "feature sharing advantage" describes a similar effect with segmental features such as place and voicing. The variance analyses revealed that Trial is significant by-target ($p < .05$), and reaches only the 0.065 level of significance by-subjects ($p = .065$). Group is highly significant ($p < .0005$ and $p < .001$, respectively). The interaction is not significant.

Table 3. *Percentages of correct detections for target-present trials*

Stimuli	Experimental trial	Control trial
Word NS	92%	92.9%
Word S	72.3%	68.8%
Pseudoword NS	97.3%	89.3%
Pseudoword S	96.4%	89.3%
Mean	89.5%	85%

Results of d'scores (see Table 4)

One problem for the interpretation of illusion rates calculated only on the basis of Fds on target-absent trials is that Fds could occur more frequently in E than in C trials because the stress pattern corresponding to the one of the target can only be

perceived in E trials. It might have some biasing effect at the response level. It was important to assess whether false recombinations of stress pattern and segmental string actually occurred at the *discriminability* level. For this reason, we calculated a further illusion rate on the basis of d' score, from the Signal Detection Theory. d' score is more reliable than a score based only on Fds, since d' gives a response bias-free index of discriminability. It depends on both Fds on target-absent trials and correct detections on target-present trials. An Ed' and a Cd' were calculated. Illusion rate on d' is calculated by dividing Ed' scores by both Ed' and Cd' scores. The hypothesis that stress pattern can recombine erroneously with segmental string predicts a situation of lower discriminability in the E trial than in the C trial (Ed' < Cd'): an illusion rate on d' < 0.5 signals the occurrence of those recombinations.

The illusion rate is lower than 0.5 only for the W S stimuli sharing the final syllable. Variance analyses show that Trial is not significant, but Group is highly significant ($p < .0005$ and $p < .025$, respectively). The interaction approaches significance, both by subject and by target ($p = .054$ and $p = .07$, respectively). Trial is significant only for W S stimuli ($p < .005$). Thus, on the basis of d' scores, it seems that stress pattern can be analyzed separately from segmental string.

Table 4. *Illusion rates on d' and standard deviation (in parentheses)*

Stimuli	Illusion rate on d'	
Word NS	0.490	(0.089)
Word S	0.258	(0.189)
Pseudoword NS	0.542	(0.043)
Pseudoword S	0.538	(0.088)
Mean	0.457	

DISCUSSION

The results suggest that, under certain conditions, subjects can experience the illusion of hearing a word, when the phonemic information is given to one ear and the lexical stress information to the other ear. Thus, it seems that before target recognition, in other words at some prelexical level, stress pattern and segmental string can be represented separately, otherwise they could not recombine erroneously. This outcome is not inconsistent with the hypothesis postulated by plurilinear phonological theories that stress pattern and segmental string to which it is associated form separate representations at the mental lexicon.

Illusion rates calculated on the basis of *d' scores* are significant in only one case, namely when the stimuli are words sharing the final syllable. Thus, false recombinations of stress pattern and segmental string can apparently occur at a discriminability level, which means that these phonological properties were, at some time during the recognition process, represented separately. Given the suggestion that separate representation of segmental string and stress pattern only occurs for syllable-sharing stimuli, it seems that separate representation does not mean independent processing. Whether stress pattern separates or not from, and recombines or not with, a segmental string would depend on the relation between the segmental strings themselves. Separation would not occur, anyway, before the dichotic stimuli interact with one another. Illusions might be related to constraints at the recombination stage. Further study of these issues is obviously required.

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