SPEAKING RATE EFFECTS IN CATALAN AND ENGLISH. A CROSS-LANGUAGE STUDY

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RESUMEN

Investigaciones realizadas dentro del marco de la percepción del habla han permitido dar cuenta de la influencia de algunos aspectos contextuales en la percepción. Se ha comprobado por ejemplo que la velocidad de habla afecta ciertos parámetros temporales, tales como el VOT o tiempo de iniciación vocálica, causando una alteración del mapa perceptivo entre la señal acústica y la estructura fonética, al desplazar los límites entre lo que en percepción categorial se denomina categoría fonética.

Con este estudio pretendíamos averiguar cuáles eran los efectos de la velocidad de habla en la producción y percepción de /t/ en inglés y catalán. El análisis acústico de las producciones de ambos grupos de hablantes corroboró nuestras expectativas de que la duración del VOT en inglés -y fase de silencio en catalán-, se ajustaban a la velocidad de habla, adquiriendo valores más bajos en el habla rápida y más altos en el habla lenta.

Desde el punto de vista perceptivo, sin embargo las pruebas piloto llevadas a cabo con dos sujetos -uno para cada lengua- demostraron que los oyentes no ajustaban su percepción a la velocidad de habla como ocurría en estudios anteriores para el inglés. Ello nos lleva a la sospecha de que el ajuste de la percepción a la velocidad de habla se produce sólo en los límites entre categorías fonéticas y no a nivel interno de categoría. De ser eso cierto, estaríamos en desacuerdo con Miller y cols. cuando afirman que la influencia del contexto - en este caso ejemplificado en la velocidad de habla- no se limita a la región limítrofe entre dos categorías sinó que se extiende al centro de la categoría, desplazando la localización de lo que se denomina "prototipo" o "mejor ejemplar" de la categoría.

ABSTRACT

Research on speech perception has provided growing evidence about the role of some context effects on speech perception. It has been proved that speaking rate influences such temporal parameters as VOT, causing an alteration of the perceptual mapping between acoustic signal and phonetic structure by shifting the boundaries between phonetic categories.

In this study we intended to find out the effects of speaking rate in the perception and production of /t/ in English and Catalan. The acoustic analysis of the production materials confirmed our prediction that both groups of speakers adjusted to speaking rate but in different ways. The English group varied the duration of VOT, whereas the Catalan group varied the duration of the closure interval. The length of both parameters increased in the slow rate and decreased in the fast rate.

The perceptual tasks performed by the two pilot subjects -one for each language- showed that there were no signs of a perceptual adjustment to speaking rate as it was found in previous literature. This lead us to suspect that maybe the perceptual adjustment to speaking rate takes place only at the boundaries between phonetic categories but not within the category. This would not be in accord with the findings of Miller and cols., in which they claim that the effects of context are not limited to the boundary region, but they extend to the centers of categories, resulting in a systematic shift in the location of the category's best exemplars or *prototypes*.

1. INTRODUCTION

Considerable research over the past few decades has dealt with the effects of speaking rate in speech production and perception. Miller and Volaitis (1989) found that in the production of English stops, the acoustic parameter known as VOT, shortens as speaking rate increases. This rate-dependent effect was also observed in perception: a change in speaking rate as reflected in overall syllable and sentence duration, altered the perceptual mapping between acoustic structure and phonetic category, causing a shift of the boundaries between phonetic categories. In a subsequent study (Volaitis and Miller, 1992), they provided evidence that a listener's adjustment for speaking-rate extends throughout a phonetic category. Thus, slowing sentence-rate moved the location of the best category exemplar or phonetic prototype.[1] Finally, Wayland, Miller and Volaitis, (1993) compared the effects of syllable-level and sentence-level speaking rate on phonemic perception. Their results indicated that sentence-level rate like syllable-level rate, does influence the perception of the stimuli within the category, shifting the placement of the best-exemplar range. [2]

Schmidt and Flege (1996) examined the speaking rate effects in the production of stops by English and Spanish monolinguals and two groups

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[1] Phonetic categories have internal perceptual structure: some members of a given category are considered better examples -more prototypical than others. In other words, all stimuli within a category are not perceived as equivalent, but vary in category goodness. (Miller and Volaitis, 1989)

[2] The mean VOT value for the fast rate sentences (350 words per minute) was 74 ms, the lower and upper limits of the phonetic category were found at 53 and 102 ms, respectively. For the slow rate (120 wpm) the mean VOT value was 89 ms and the limits of the category where 75 and 116 ms.

of Spanish/English bilinguals. They found that while the four groups produced comparable changes in sentence duration across the three rates, the speaking rate changes had a minor effect on the VOT in stops spoken by the Spanish than the English monolinguals. It remained unanswered, however, whether this was due to the fact that the short-lag values of Spanish stops allowed little variation for each rate, or whether the speaking rate effects for Spanish stops were to be seen in other acoustic parameters.

Flege's approach to L2 acquisition "Speach Learning Model" (Flege, 1992) hypothesizes that a second-language learner can establish a new phonetic category "for an L2 sound that differs phonetically from the closest L1 sound" provided that the learner is capable of discerning "at least some of the phonetic differences between the L1 and the L2 sounds". Schmidt and Flege (1996), claim that one way of testing for category formation is to study how speaking rate influences the perception and production of non-native speech.

The aim of the present study is to examine the effect of changes in speaking rate in English and Catalan. If the results confirm our prediction that, like Spanish, VOT does not shorten in the Catalan monolingual's production of /t/ as speaking rate increases, it will allow us to establish a clear cross language difference between both languages, which can be used in subsequent studies to assess the effects of speaking rate in non-native speech.

2. PRODUCTION

Various comparative and cross-language studies have examined the acoustic differences between stops in English and the Romance languages. English /p t k/ in initial position are realized as voiceless unaspirated stops having long-lag voice onset time (VOT) values, whereas Spanish /p t k/ are

realized as voiceless unaspirated stops with short-lag VOT values. These differences are important in that they have a substantial effect on the production difficulties encountered by Spanish speakers of English as a second language.

Laeufer (1996) reported that the absolute durations of the stop closure interval were significantly longer in French than in English. The cross-linguistic difference amounted to 29 ms for voiceless stops and 17 ms for voiced stops. Similarly, an investigation about native Spanish and Spanish-English bilinguals production of word-initial stops (Green et alii, 1997), showed that closure interval duration -not VOT- served to distinguish between voiced and voiceless stops. Their findings raised questions about the role of this parameter in the perception of voicing by Spanish speakers.

A study by Martínez Celdrán (1993) for Spanish bilabial stops answers the question. In a perceptual experiment, subjects audited a series of two-syllable words with a bilabial stop in medial position, in which the burst had been removed and the duration of the closure interval was varied in 8.8 ms steps, ranging from 26 ms to 220 ms. The results of the test revealed that listeners categorized /b/ within the 26-61 ms range.The boundaries of its voiceless counterpart /p/ were found at 70 ms (lower limit) and 140 ms (upper limit). Therefore evidence is provided in favour of the role of closure-interval duration as a cue to distinguish the two categories /p/ and /b/ in Spanish.

Given the outcomes of the research detailed above, we hipothesized that the effects of speaking rate in Catalan were to be seen not in VOT but probably in the stop closure interval. Using a magnitude production task, we intended to see whether Catalan and English monolinguals showed different speaking rate effects. We knew from previous research (Schmidt and Flege, 1996) that English speakers varied VOT in a systematic way

depending on whether they were talking in a fast, slow or normal fashion but that Spanish speakers did not quite show the same effects[3].

2.1 Method

2.1.1. Subjects

The production materials were elicited by seven native speakers of American English with a mean age of 28 years (range: 21-35), and by seven native speakers of Catalan with a mean age of 24 years (range: 20-29). All 14 subjects were female. The American subjects were recorded in Birmingham, Alabama; and the Catalan speakers were recorded in Barcelona. The native English speakers were monolingual; the Catalan speakers could understand Spanish, but did not speak that language on a regular basis. (Even if they did, it would not be expected to influence their productions.)

2.1.2. Speech Materials

Each subject elicited a series of nonwords (*papo, dapo, tapo*) in a carrier sentence at five speaking rates in the sequence: very fast, fast, normal, slow, very slow. The test items were arranged in a pseudo-randomized list three times each. The carrier sentence that was used for Catalan was *"No diguis ___ mai mes" (Never say ___ again).* A similar

[3] At this point it should be made clear that the modest correlation between /t/ VOT and speking rate of the Spanish subjects in the Schmidt and Flege study has to be questioned . Given the short-lag values of VOT in Spanish, any small change would alter significantly the slope of the linear regression .

sentence was chosen for English: *"I do miss ___ my friend"* . This way the nonwords were in the same phonetic context in both languages.

The subjects were told that they were to produce the nine-item list at five different rates. *Very fast* was defined as "as fast as you can speak without dropping sounds or distorting your speech" and *very slow* was defined as "as slow as you can speak without introducing pauses". These rates were given the values of 1.5, 1 and 0.5. The other two rates *fast* (defined as "halfway between *very fast* and *normal*") and *slow* (defined as "halfway between *very slow* and *normal*") were assigned the values of 1.25 and 0.75, respectively.

2.1.3. Procedure

Both English and Catalan subjects were recorded by the same experimenter in a sound booth using a portable DAT recorder and a "Shure SM58" microphone. They were given some training until they were comfortable with the task, i. e. until they could self-control and vary their speaking rate as requested.

Two different methods were used in the magnitude production task: the *block method* and the *sentence method*. As subjects tend to stabilize at one particular rate, the former was preferred for the start. Therefore, subjects began by reading the nine sentences in the list at the very fast rate, then they continued to read the list a second time at the fast rate and so forth, following the order outlined above (very fast, fast, normal, slow, very slow). For the "sentence method" the task consisted on reading each single sentence at five rates. Most subjects reported this rapid changing of rates to be more difficult.

A total of 420 samples were obtained for each language (3 tokens x 5 rates x 2 methods x 7 subjects). The production materials were later digitized at 22.0 kHz with 16-bit accuracy using the Syntrillum Software Corporation waveform editor "Cool Edit" .

2.1.4 Data analysis

For the purpose of the present study only the *tapo* tokens were measured. A total of six temporal intervals were meausred in each of the tapo tokens: the duration of /t/ closure, the VOT of /t/, the duration of the first vowel, the duration of /p/ closure, the VOT of /p/, and the duration of the second vowel.

Below the criterion for the measurement of each phonetic "segment" are detailed:

A:/t/ closure: from the end of the frication noise of the preceding /s/ to the /t/ release burst (when more than one release burst was present the first burst was taken).

B:VOT of /t/: from the release burst to the first positive amplitude peak of the periodic portion of vowel 1.

C:Vowel 1 duration: periodic portion of the waveform.

D:/p/ closure: from the last positive peak of the periodic portion to the /p/ release burst.

E:VOT of /p/: from the /p/ release burst to the first positive amplitude peak of the periodic portion of vowel 2.

F:Vowel 2 duration: periodic portion of the waveform. The boundary with the following nasal segment was established at the change of waveform pattern and/or decrease of amplitude peak.

From the total speech data, only a few tokens could not be meassured (missing tokens). Below we give the breadown by (1) language and (2) phonetic segment.

Catalan: 1 /t/ closure, 1 /p/ VOT.

English: 6 /t/ closures, 2 /t/ VOT, 2 vowel-1 durations, 2 /p/ closures, 7 /p/ VOT, 4 vowel-2 durations.

2.2. Results

2.2.1. Word duration

The mean durations of the word *tapo* produced at the five speaking rates are shown in fig.1. For the two languages, the duration of *tapo* tokens for the slow and very slow rates was longer than for the normal-rate; the latter were longer than fast-rate and very-fast-rate tokens. On average, sentences spoken by the Catalan speakers at the very fast and fast rate were 20% and 10% shorter than were sentences spoken at the normal rate, and the very-slow and slow sentences were 40% and 17% longer than the normal-rate sentences.[4]

[4] See table II (appendix).

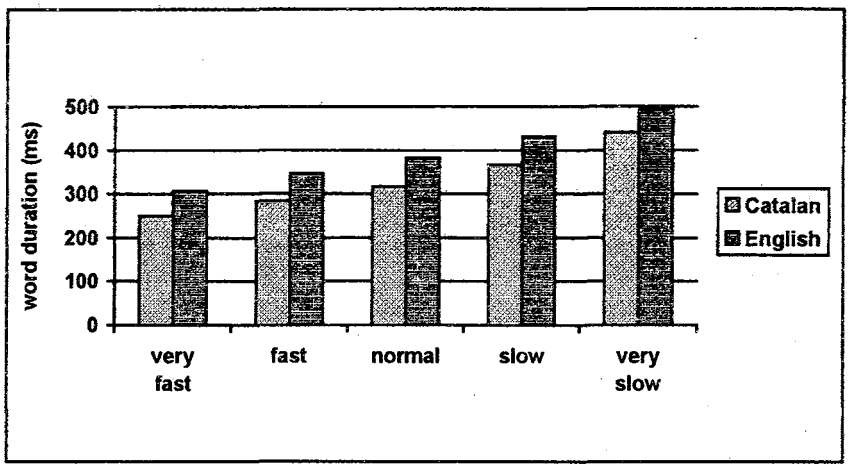

Fig. 1. The mean duration of the word tapo spoken at the five different speaking rates by Catalan and English monolinguals.

The English speakers performed in a similar trend. Their very fast and fast productions were 20% and 9% shorter than the normal ones. Notice than the percentages virtually replicate those of the Catalan speakers. For the slow and very-slow rates, the English speakers did not slow down their speaking rates as much as the Catalans did. Their very slow and slow-rate sentences were an average of 13% and 30% shorter than the normal-rate sentences.

2.2.3. Voice Onset Time

The mean VOT values obtained for /t/ in the non-word *tapo* are shown in fig. 2. The English speakers increased VOT systematically as a function of speaking rate, however this was not the case for the Catalan

speakers for whom VOT values remain almost constant across rates. Notice that there is no overlapping between the long-lag VOT values of English /t/ -which range from 35 ms to 75 ms- and the short-lag values of Catalan /t/, which remain within the 14 / 15 ms range.

As we expected, Pearson correlations[5] revealed that word duration was significantly correlated with VOT in English ($r = 0.697$, $n = 200$, $p = 0.000$) but not in Catalan ($r = 0.313$, $n = 208$ $p = 0.0000$).

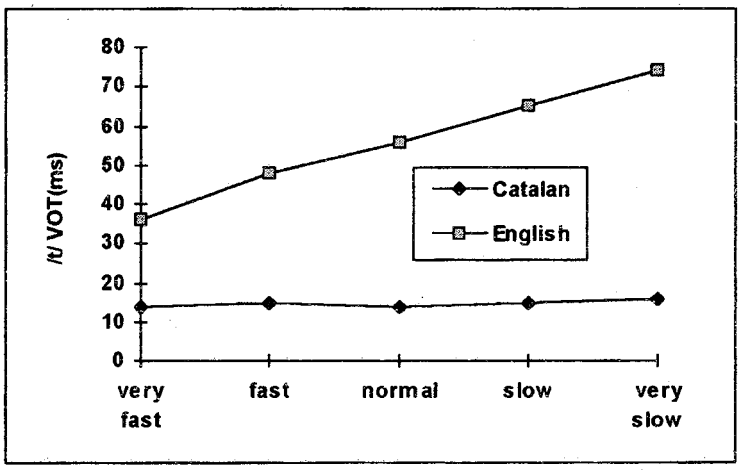

Fig. 2. The mean an /t/ VOT values of the non-word tapo spoken at five rates by Catalan and American English monolinguals.

[5] See table III for further detail.

2.2.3. *Closure interval*

The mean closure interval durations of /t/ are plotted in figure 3. Comparing this plot with the one obtained in figure 2, one can see how both groups show just the opposite trends. The Catalan speakers increased the closure interval durations systematically as speaking rate decreased. The mean /t/ closure durations range from 52 ms for the very fast rate to 90 ms for the very slow. However the English closure intervals show little change across the rates. The values remain within a range between 55-65 ms and virtually do not overlap with the Catalan values.

Pearson correlations between closure interval and word duration yielded a significant effect for Catalan ($r = 0.752$, $n = 206$, $p = 0.0000$) but not for English ($r = 0.261$, $n = 195$, $p = 0.0002$).

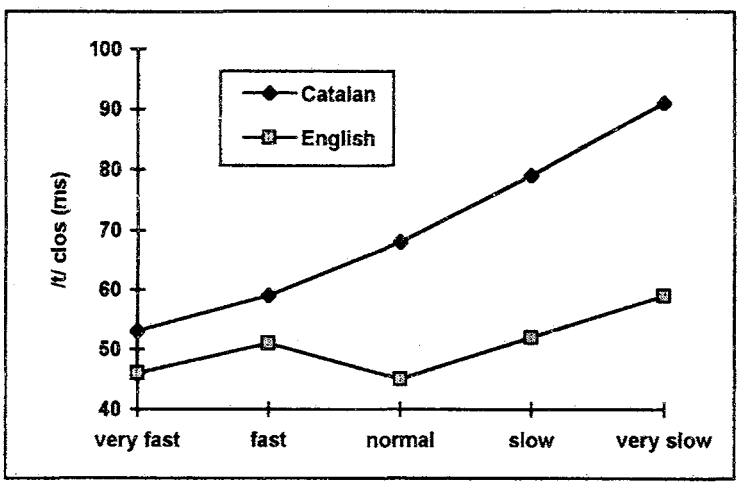

Fig. 3. The mean closure interval durations of /t/ in the word "tapo" spoken at five rates by Catalan and American English monolinguals.

3. PERCEPTION

The magnitude production study was replicated by a perception study. The primary aim was to know whether listeners would show a similar rate-dependent processing in perception. If that were the case, when presented with triads in which the /t/ closure interval or the /t/ VOT had been shortened and lengthened in two of the tokens, they would show a preference for the stimuli that had values apropiate for each rate.

3.1. Stimuli

The stimuli used for the two perception experiments were the same speech materials from the magnitude production task. The productions of Catalan subject no. 7 and English subject no. 4 were selected because of their similar changes across speaking rates (see Table II). The /t/ closure values of the 30 *No diguis tapo mai mes* sentences were edited to perfectly fit the function that was obtained from real data (shown in table IV). The same procedure was used to edit the /t/ VOT of the English sentences elicited by English subject no. 4. The "optimal" closure and VOT durations were predicted from the regression equation of the linear scatterplots showed in figs. 4 and 5. This equation takes the form:

$$Y = a + bX$$

where Y = estimated Y score, a = intercept, b = slope, and X = X variable score. Therefore, for Catalan:

$$/t/ \text{ closure} = 3.38 + (\text{cntx dur} * 0.0796)$$

and, similarly for English:

$$/t/ \text{ VOT} = 0.0245 + (\text{cntx dur} * 0.0825).$$

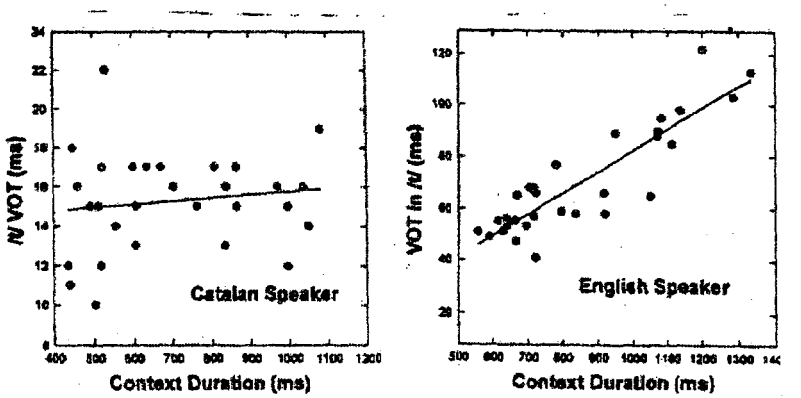

Fig. 4: Linear regression scatterplots between sentence duration and /t/ closure interval for Catalan speaker no. 7 (C7) and English speaker no. 4 (E4).

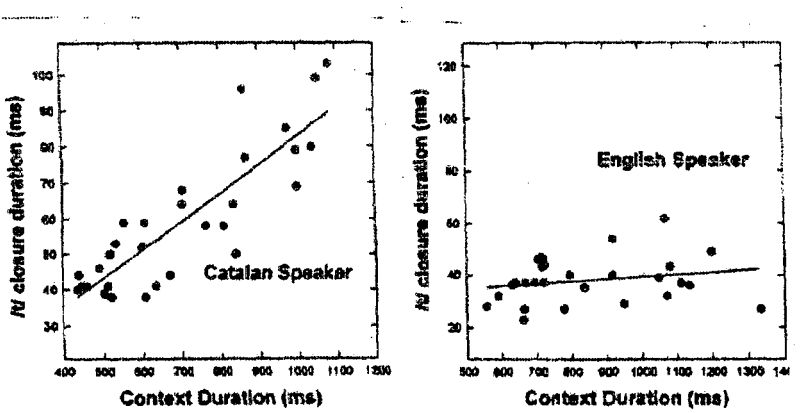

Fig. 5: Linear regression scatterplots between sentence duration and /t/ closure interval for Catalan speaker no. 7 (C7) and English speaker no. 4 (E4).

3. 2. Procedure

Once the "optimal' /t/ closure and /t/ VOT values were obtained, the 30 Catalan sentences (*No diguis tapo*) and the 30 English ones (*I do miss tapo*) were randomly arranged in two different sets for subsequent presentation in a *rate for goodness* test. This task consists on rating stimuli according to their speaking rate using a 1 to 7 scale. The very fast rate was given the value 1, the normal rate the value 4 and the very slow the value 7. The firs part of the carrier sentence was kept because it was the only way listeners could make judgements about closure durations. We thought that this straightforward task would serve as priming for the second test, in that it would provide listeners with a slight notion of the kind of stimuli they would be hearing to in the second experiment.

For the second perception experiment we used a new perceptual testing procedure developed at the Biocommunication Research Lab. of the University of Alabama at Birmingham. This tool uses the "oddity format" procedure, i.e. subjects must decide which one stimulus differs from all other stimuli in the same trial. The fact that an "odd item out" can occur in any position increases uncertainty. Flege (1997) assessed the efectiveness of CDT (*Categorical Discrimination Test)* adminisering the test to listeners of nine different languages. The tool proved to be a stable measure of L2 vowel perception.

The stimuli for the CDT were a set of six tokens selected from table IV for both, English and Catalan. The next step wast to create three series of stimuli for each of the two languages which were named as: the *base series*, the *long series* and the *short series*. Each series consisted of a set of five sentences of the type *No diguis tapo* or *I do miss tapo.* As with the rate for goodness experiment, here it was necessary to keep the first part of the carrier phrase so that we could examine the effects of different /t/ closure interval durations.

The Catalan *base stimuli series* consisted of sentences with /t/ closure values apropiate for each rate (or context duration) obtained from the linear regression scatterplots (figs. 4 and 5). Similarly, the English *base stimuli series* contained the sentences with the /t/ VOT values apropiate for each rate or context duration. For the other two series, the /t/ closure of the Catalan sentences and the /t/ VOT of their English counterparts were edited. For the *long series* both parameters were lenghened in 20 msec. steps and for the *short series* they were shortened also in 20 msec. steps. A total of 18 stimuli were obtained for each language (6 base + 6 short + 6 long).

The two sets of stimuli were arranged in triads. Each triad was made of a base stimulus and the correspondent short and long stimuli - in which /t/ closure or /t/ VOT had been shortened or lengthened for each case. The triads were randomized to be presented in a *Categorical Discrimination Test (CDT)* in which subjects were asked to choose the best example of /t/.

Each triad was presented 18 times, this made it possible for each stimulus to occur 6 times in each of the three different positions (first, middle and third). The ISI (inter stimulus interval) was 0.8 sec. and the interval between each response and the presentation of the next trial was fixed at 1.5 sec. A brief period of familiarization preceded the actual test so that listeners became acquainted with the task

3.3. Results

3.3.1. "Rate for goodness" experiment

Prior to administering the actual tests to two groups of native Catalan and English listeners, we conducted two pilot experiments. A native

Catalan speaker listened to the Catalan stimuli and a native English speaker listened to the English set. The results of the two pilot subjects for the *rate for goodness* experiment are shown in figure 6. As it can be seen from the two plotted lines, both listeners rated the fast sentences with higher scores and they gave lower scores to the slow-rate sentences.

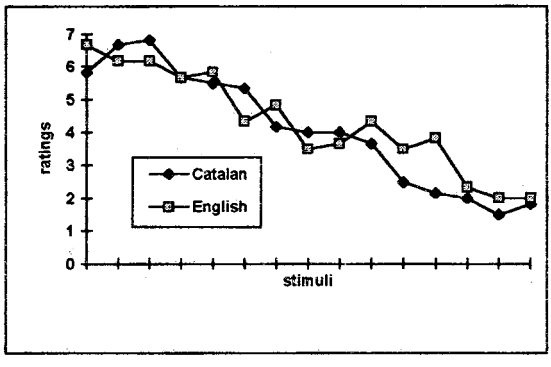

Fig. 6. Responses of the rate for goodness experiment by Catalan and English pilot subjects (7 = very fast, 1 = very slow)

3.3.2. Discrimination Experiment

Contrary to our expectations, both the Catalan and the English pilot subjects failed to show any speaking rate effects in perception. To be judged successful, the CDT should yield a low error rate (the Catalan listener failed 163 trials out of 208). Both subjects reported that they could not hear any difference between the three stimuli in the trials, even though /t/ VOT and /t/ closure had been edited in 20 ms steps so that only one stimulus had the apropiate closure duration or VOT for a specific speaking rate. Given these outcomes we settled two other pilot experiments for the

Catalan continuum. In the second pilot experiment /t/ closure duration was edited in 30 ms steps. Again the correct responses obtained for the Catalan pilot subject were only 44 out of 208 (20%)[6]. Finally we set up a third pilot test, in which the stimuli were presented in six sets, beginning with the very fast rate and ending with the slowest rate. We assumed that presenting the stimuli in an order, subjects would adjust their perception to different speaking rates more easily. However the results were not in accord with our assumptions. For the third time, the pilot subject's correct responses were only 20%. Viewing such results the test was not administered to any group of subjects.

4. DISCUSSION

4.1. Production

The English speakers showed the expected rate-dependent effect on VOT. They produced initial /t/ with significantly shorter VOT values at the fast and very-fast rates than at the normal rate, and with significantly longer VOT at the slow and very slow rates compared to the normal rate. The Catalan speakers, on the other hand, showed a rate-dependent effect on closure interval durations. That is, they produced initial /t/ with significantli longer /t/ closure durations at the slow rate than at the fast rate.

The present study provides evidence for a clear cross-language difference between speaking rate effects on stops produced by Catalan and English speakers. Both groups of speakers show a rate-dependent effect in production, however this effect takes two different forms in each language. Whereas the English speakers shorten VOT as speaking rate increases,

[6] Notice that the percentage of correct responses does not even exceed the range of chance, which is fixed at 30% of correct responses.

Catalan speakers stick to constant VOT values across the rates, instead they shorten and lengthen the duration of the /t/ closure interval depending on whether they are speaking in a fast or slow rate.

Further researched should be aimed at how speaking rate influences the speech Catalan speakers of English. If, like the English speakers, the effects of speaking rate are to be seen in VOT, we will be facing some evidence for the first signs of category formation.

4.2. Perception

The outcomes of the two perception experiments presented in this paper came to a surprise. The subjects who participated in the Miller and Volaitis (1989) and Flege and Schmidt experiments showed a perceptual sensitivity to very small variations in VOT (5 ms, 10 ms and 20 ms). One wonders why the English pilot listener was no able to notice the difference between three stimuli in which VOT had been varied in 20 ms. steps.

Given the the floor effects of our experiment we tried to find the reasons why both pilot listeners failed to perceive variations in VOT/ closure interval, thus failing to show a rate-dependent processing of speech. Below three hipothesis are detailed

a). Stimuli.

In their experiments, Miller and cols. used synthetic CV stimuli of 125 ms duration for the fast rate and 325 ms for the slow rate[7]. Thus the difference of the two rates amounts to 200 ms. The non-words used in our

[7] The stimuli used in the Flege & Schmidt study were those used by Miller and Volaitis.

test were spoken at five different rates and the overall syllable duration increased in 40 ms steps - the real values ranged from 307 ms for the very fast words and 493 ms for the very slow tapos-. We hipothesize that maybe listeners are not sensitive to very short time differences as 40 ms, when these occur within the same phonetic category. If that were true, we should start questioning some of the findings of Miller and cols.,i. e. the claim that the adjustment for rate is not confined to the region of the category boundary but extends throughot the phonetic category. This would imply that speaking rate opperates at a phonetic category level[8], and not at an auditory level as Miller and Volaitis claim.

b) Procedure

The *tapo* items used in our perception test were embedded in the carrier sentences *No diguis tapo* or *I do miss tapo*. We thought that using sentences instead of words would enhance the listener's adjustment for rate. In view of the poor results, we considered the possibility that the carrier sentence could have had a masking effect, thereby deviating the listener's attention from the main focus of interest, which was the /t/ sound. However the findings of Miller & cols. (1993) confirmed that the rate-dependent nature of speech perception operates at sentence-level as well as syllable-level. Therefore, we discarded any chance of the carrier sentence having a masking effect on the listener

There is another aspect of the test procedure that might have contributed to the floor effects of the discrimination task. Looking at it in retrospect, maybe presenting three sentences in a triad prevents the listener from retaining the acoustic information in short-term memory that enables him to make a judgement and choose the best example of /t/.

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[8] The Catalan pilot subject reported that some of the stimuli sounded as examples of the voiced dental stop /d/ instead of /t/.

Future researh should focus on testing listeners using different stimuli and test procedures. It would be interesting to see the responses to stimuli spoken at two rates instead of five. We must keep in mind that in the stimuli used by Miller&cols., the between-rate difference as reflected in syllable duration amounted to 200 ms, whereas in our stimuli this difference was of only 40 ms.

5. ACKNOWLEDGEMENTS

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6. APPENDIX

Rate	*Lang.*	*/t/ closure*	*/t/ VOT*	*vowel-1 duration*	*/p/ closure*	*/p/ VOT*	*vowel-2 duration*	*word duration*
very fast	Eng.	46 (12)	36 (11)	83 (16)	61 (8)	19 (6)	61 (13)	307 (21)
	Cat.	53 (9)	14 (2)	60 (14)	55 (7)	12 (2)	56 (7)	250 (28)
fast	Eng.	51 (13)	48 (9)	89 (14)	65 (11)	21 (6)	72 (13)	347 (28)
	Cat.	59 (12)	15 (2)	71 (13)	64 (4)	14 (2)	61 (12)	284 (36)
normal	Eng.	45 (10)	56 (9)	104 (12)	70 (11)	21 (5)	88 (14)	382 (26)
	Cat.	68 (17)	14 (2)	81 (12)	69 (10)	15 (3)	68 (10)	316 (43)
slow	Eng.	52 (14)	65 (9)	115 (15)	79 (16)	21 (6)	107 (24)	431 (49)
	Cat.	79 (20)	15 (1)	99 (13)	81 (9)	17 (3)	78 (9)	367 (41)
very slow	Eng.	59 (16)	74 (15)	126 (23)	85 (20)	22 (6)	131 (36)	493 (79)
	Cat.	91 (14)	16 (1)	118 (16)	98 (8)	19 (4)	98 (15)	441 (33)

Table 1. The mean duration of six phonetic segments in the nonwords tapo produced at five rates by native speakers of English and Catalan. Each mean is based on the mean value obtained from seven subjects. "Word" duration is the sum of the preceding six segments. Standard deviations are in parentheses.

L1	*SUB*	*Very Fast*	*Fast*	*Normal*	*Slow*	*Very Slow*
Eng	E2	312 (-25%)	375 (-9%)	414	505 (+22%)	591 (+43%)
	E3	295 (-13%)	313 (-8%)	339	385 (+14%)	420 (+24%)
	E4	275 (-26%)	318 (-14)	371	456 (+23%)	581 (+57%)
	E5	276 (-23%)	324 (-10%)	359	369 (+3%)	447 (+25%)
	E6	317 (-25%)	378 (-11%)	423	495 (+17%)	569 (+35%)
	E7	329 (-15%)	351 (-9%)	388	420 (+8%)	431 (+11%)
	E8	312 (-15%)	357 (-3%)	369	393 (+6%)	431 (+17%)
	average	-20%	-9 %		+13%	+30%
Cat	C1	278 (-28%)	328 (-15%)	384	433 (+13%)	494 (29%)
	C2	268 (-21%)	293 (-13%)	339	395 (+17%)	454 (34%)
	C3	280 (-21%)	327 (-8%)	356	376 (+6%)	407 (14%)
	C4	242 (-13%)	274 (-2%)	280	330 (+18%)	464 (66%)
	C5	240 (-15%)	265 (-6%)	284	346 (+22%)	382 (35%)
	C6	240 (-18%)	261 (-11%)	294	373 (+27%)	432 (47%)
	C7	203 (-27%)	230 (-17%)	277	330 (+19%)	431 (56%)
	average	-20%	-10 %		+17%	+40%

Table II: Rate changes shown by the seven native speakers of Catalan and English across the five rates. [9]

[9] These values were the result of calculating the mean values between the six word duration measurements obtained for each subject and speaking rate.

	T-CLOS / WORD1	*T-CLOS / WORD2*	*VOT / WORD1*	*VOT / WORD2*
E2	0.67	0.55	0.58	0.62
E3	0.07	-0.11	0.75	0.81
E4	0.31	0.23	0.92	0.93
E5	0.37	0.24	0.75	0.76
E6	0.18	0.06	0.87	0.90
E7	0.44	0.18	0.73	0.81
E8	0.69	0.42	0.74	0.69
average	0.45	0.26	0.62	0.69
C1	0.93	0.86	-0.12	-0.02
C2	0.88	0.83	0.04	0.09
C3	0.81	0.67	-0.38	-0.33
C4	0.92	0.88	0.58	0.61
C5	0.92	0.87	0.71	0.71
C6	0.91	0.86	0.42	0.44
C7	0.94	0.90	0.17	0.17
average	0.86	0.75	0.31	0.32

Table III: Pearson correlations between /t/ closure and word duration (Catalan) and /t/ VOT and word duration (English) and Catalan. Word1 includes all segments in the word tapo, word-2 includes all segments except /t/ closure.

/t/ closure (real values)	/t/ closure (predicted "optimal" values)	NUMBER of TOKEN	/t/ VOT (real values)	/t/ VOT (predicted "optimal" values)
39	43	1	56	53
40	38	2	53	53
44	38	3	55	51
41	44	4	51	52
50	45	5	68	58
59	47	6	65	55
44	57	7	77	64
52	51	8	53	57
59	52	9	41	60
50	70	10	68	59
64	70	11	58	69
77	72	12	58	76
69	83	13	122	99
79	83	14	98	94
103	90	15	88	88
41	39	16	51	46
46	42	17	49	49
41	40	18	55	55
38	45	19	47	55
53	46	20	66	60
38	52	21	57	59
41	54	22	59	66
68	59	23	89	78
64	59	24	66	75
58	64	25	90	85
96	72	26	65	87

58	68	27	85	92
85	81	28	95	89
80	86	29	113	110
99	87	30	103	106

Table IV: real and predicted /t/ closure and /t/ VOT values for Catalan and English.

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