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Subsidia: Herramientas y Recursos para las Ciencias del Habla

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Subsidia: Tools and Resources for Speech Sciences is a scientific publication arising from the organisation of a congress with the same name, carried out in the city of Málaga (Spain) in June, 2017. Its main goal is to give voice to tools and resources developed with the aim of facilitating research in the field of speech sciences. This framework embraces subjects such as phonetics, experimental phonetics, phonology, discourse analysis or dialectology, among others. This book, outcome of the collaboration of expert researchers on their respective areas, aims to be an aid to the scientific community in the sense that it compiles and depicts a series of materials that, we hope, may result beneficial to keep moving forward in the research.

The papers collected in this volume are a selection of those submitted to the above-mentioned congress, and have undergone peer review.

Subsidia: Herramientas y Recursos para las Ciencias del Habla es una publicación científica resultante de la organización del congreso del mismo nombre desarrollado en la ciudad de Málaga (España) en junio del año 2017. Su objetivo principal es dar a conocer herramientas y recursos desarrollados con el objetivo de facilitar la investigación en el campo de las ciencias del habla. Dentro de este marco se engloban disciplinas tan variadas como la fonética experimental, la fonología, el análisis del discurso o la dialectología, entre otras. Este libro, resultado de la colaboración de investigadores expertos en sus respectivas áreas, pretende ser una ayuda a la comunidad científica en tanto en cuanto recopila y describe una serie de materiales que esperamos resulte provechoso para continuar avanzando en la investigación.

Los artículos recogidos en este volumen son una selección de los que se presentaron en dicho congreso y han pasado una evaluación por pares.

Methodological issues in the assessment of cross-language phonetic similarity

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ABSTRACT: The assessment of cross-linguistic similarity remains a crucial methodological issue in speech perception and second language acquisition research. This is so because models of second language speech base their predictions precisely on the degree of similarity between native and non-native sounds. However, it is still unclear what the best approach to cross-language comparisons is. This paper discusses a few key issues in the assessment of cross-linguistic similarity, focussing on perceptual methods, by reporting some results from a series of studies involving native and non-native speakers of English, Catalan and Spanish. The issues discussed include the type of task, the nature and amount of the stimuli used, the effect of amount of L2 experience on cross-language perception, and the use of L1 data as control data. The paper advocates for the use of multiple methods and bidirectional data, and also presents a new approach involving online processing tasks.

Keywords: second language speech; cross-linguistic similarity; speech perception.

RESUMEN: La evaluación de la similitud entre lenguas sigue planteando problemas metodológicos en la investigación sobre percepción del habla y adquisición de segundas lenguas. Esto es así porque los modelos de habla en segundas lenguas basan sus predicciones precisamente en el grado de similitud entre los sonidos nativos y no nativos. Sin embargo, todavía no está claro cuál es la mejor manera de realizar esa comparación entre lenguas. Este artículo analiza algunos problemas clave en la evaluación de la similitud entre lenguas. Para ello, se centra en los métodos perceptivos y aporta resultados de una serie de estudios con hablantes nativos y no nativos de inglés, catalán y español. Los aspectos analizados incluyen el tipo de tarea, la naturaleza y la cantidad de estímulos utilizados, el efecto de la cantidad de experiencia con la L2 sobre la percepción interlingüística, y el uso de datos de la L1 como control. El artículo defiende el uso de múltiples métodos y datos bidireccionales, y también presenta un nuevo enfoque basado en tareas de procesamiento online.

Keywords: lengua segunda; similitud entre lenguas; percepción del habla.

1. INTRODUCTION

It is well-known that second or foreign language (L2) learners tend to perceive and produce target language sounds in terms of native language categories (Best, 1995; Flege, 1995; Kuhl & Iverson, 1995). According to Trubetzkoy (1969), the L1 phonological system functions as a perceptual "sieve" filtering target language (TL) sounds that as a result are categorized in terms of the closest L1 categories, at least at initial stages in the acquisition process. Models of L2 speech try explain the relationship between the level of similarity between native and non-native sounds and success in L2 category formation. For instance, the Native Language Magnet model (Kuhl, 1991; Kuhl & Iverson, 1995) claims that in the process of acquiring

the L1, a set of propotypical sound categories are developed which guide L1 perception. These prototypes also affect L2 perception, as non-native sounds are perceptually attracted to the closest L1 sound prototypes. According to the Speech Learning Model (Flege, 1995, 2003), there is a process of *equivalence classification* by which phonetically similar TL sounds are mapped on to existing L1 categories. Thus learners need to discern differences between native and target sounds in order to establish accurate categories for the L2 sounds. Best's Perceptual Assimilation Model (Best, 1995; Best & Tyler, 2007) makes a series of predictions about discriminability of TL sounds based on different patterns of perceptual assimilation of target sounds to L1 sounds.

The notion of cross-linguistic similarity, thus, is crucial in order to make predictions about the relative difficulty and learnability of target language sounds.

2. ASSESSING PHONETIC SIMILARITY

Different methods of assessing the similarity between native and non-native sounds have been suggested, including articulatory comparisons, acoustic comparisons and perceptual judgements.

Articulatory comparisons involve contrasting L1 and L2 sounds on the grounds of articulatory descriptions. While these can be informative and can provide preliminary results, they have been found to fail to reflect perceptual similarity. For example, as Strange (2007) explains, lip rounding is a redundant feature in American English for non-low vowels as non-low front vowels are unrounded and non-low back vowels are rounded. By contrast, rounding is distinctive in German and French, which distinguish between front rounded and front unrounded vowels. On the basis of this comparison, we could predict that English speakers will have trouble differentiating the French / German high front rounded and high front unrounded vowels. Results from perceptual studies, however, show that American English speakers find the contrast between French / German high back rounded and high front rounded vowels harder to discriminate than the front vowel contrast (Polka & Bohn, 1996). Strange, Levy, & Lehnholf (2004) found that American English speakers perceived front rounded vowels as English back rounded vowels rather than as front unrounded vowels, showing that perceptual judgements are better predictors of L2 discrimination ability than phonetic or articulatory descriptions.

Acoustic comparisons involve analyses of the acoustic properties of native and non-native sounds in order to determine the extent to which native and non-native categories overlap (Flege, Bohn & Jang, 1997; Flege, MacKay & Meador, 1999; Tsukada et al. 2005). For example, native and non-native vowels are typically compared in terms of their spectral properties (F1, F2, F3) and temporal properties (duration). However, discrepancies between the acoustic measurements and perceptual judgements are not infrequent (e.g., Bohn, Strange, & Trent, 1999; Stevens, Liberman, Studdert-Kennedy, & Öhman, 1996; Strange, Levy et al., 2004). For instance, Cebrian (2006) found that pairs of native and non-native vowels that had very similar degrees of acoustic similarity based on average steady state F1 and F2 measurements patterned differently when the perceptual similarity between the same pairs of vowels was examined. It is possible that additional vowel properties such as formant trajectories or f_0 need to be taken into account too in order to obtain a more complete picture of acoustic similarity. Further, acoustic characteristics vary considerably as a function of inter-speaker differences, phonetic context and prosodic context. In any case, recent proposals advocate for the use of perceptual measures, or a combination of perceptual and acoustic comparisons, as the best approach to determining cross-linguistic phonetic similarity (Bohn, 2002; Strange, 2007).

The focus of this paper is on perceptual similarity. The main issues concerning perceptual approaches to cross-language similarity are presented in the next section.

## 3. PERCEPTUAL MEASURES OF CROSS-LINGUISTIC SIMILARITY

Perceptual measures of similarity involve perceptual judgements of two kinds: indirect covert comparisons and direct overt comparisons. The former are typically represented by the paired comparison technique (rated dissimilarity tasks) and the latter by interlingual identification tasks (perceptual assimilation tasks).

3.1. Rated dissimilarity task

A rated dissimilarity task (RDT) is a paired comparison task in which listeners are presented with a pair of stimuli and they have to rate the degree of (dis)similarity between the two stimuli by means of a 7-point or a 9-point Likert scale. Figure 1 presents an example of the visual display that accompanies each trial in an RDT, using Praat (Boersma & Weenink, 2016). Flege, Munro & Fox (1994) used this technique to evaluate the perceived similarity between Spanish and English vowels. Cebrian, Mora & Aliaga-García (2011) also used it to compare British English vowels and Catalan vowels.

Rated dissimilarity tasks present pairs of stimuli representing different conditions. These may include pairs of two L1 sounds, two L2 sounds or an L1 and an L2 sound. In addition, the two members of each pair may belong to the same sound category (possibly for control purposes) or to different categories, in which case they may be from adjacent categories (e.g., English /æ/ and /ɛ/) or distant categories (/æ/ and /i/). By way of illustration, Table 1 provides an example of the results obtained by Cebrian et al. (2011) indicating the mean dissimilarity rating for each type of vowel pair.

Figure 1: Example of rated dissimilation task. Display of response alternatives and rating scale.
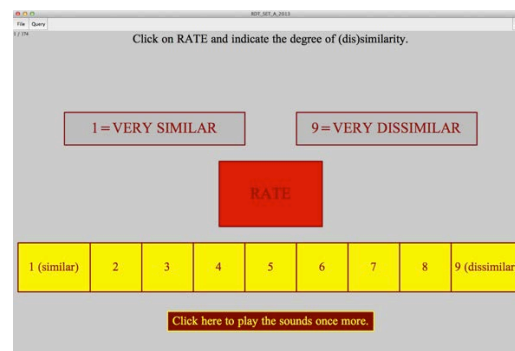
Table 1: Mean dissimilarity ratings for each type of vowel pair (1 = same, 7 = different; L1 = Catalan, L2 = English) from Cebrian et al. (2011).

Type of pair	Language	Mean dissimilarity rating (SD)
same category	L1-L1	1.7 (0.5)
same category	L2-L2	2.0 (0.6)
adjacent category	L2-L2	3.4 (0.8)
adjacent category	L1-L2	3.7 (0.6)
adjacent category	L1-L1	4.2 (0.8)

Results in this case show that adjacent L2-L2 vowels are perceived as being more similar than adjacent L1-L1 vowels, possibly showing more defined categories for L1 sounds. Cebrian et al. also found that some L2-L1 pairs obtained similarity ratings that fell within the values of those obtained by same-category L1-L1 pairs, showing that some L2 vowels are perceived as near identical to L1 vowels.

Strange (2007) argues that direct overt tasks such as the paired technique comparison (Flege et al., 1994; Cebrian et al., 2011) are problematic because in these tasks listeners do not compare a given stimulus to their own mental representations of L1 phonetic categories. Instead, listeners compare two physical stimuli: an L2 sound and an L1 sound, the latter produced by a speaker who is different from the listener. Hence, the task may not involve accessing the listener's actual own internal representations. Strange advocates for tasks that present a single stimulus to be compared with the listener's own processing categories, such as an interlingual identification task.

3.2. Perceptual assimilation task

Recent research advocates for cross-language mapping tasks or interlingual identification tasks (Bohn, 2002; Strange, 2007), also known as perceptual assimilation tasks (Guion, Flege, Akahane-Yamada & Pruitt, 2000). In this task, listeners are presented with a single L2 stimulus and have to identify it in terms of L1 categories and then provide a goodness of fit rating. These tasks have been used to examine the perceptual similarity between native and non-native consonants (Guion et al., 2000; Park & de Jong, 2008; Schmidt, 1996, 2007, among others) and vowels (Lengeris, 2009; Strange, Bohn, Trent & Nishi, 2004; Strange, Levy et al, 2004, among others). Figure 2 presents an example of the visual display of a perceptual assimilation task (PAT), illustrating the L1 (English) category responses and a 7-point rating scale to indicate the goodness of fit rating, using Praat (Boersma & Weenink, 2016).

The results of a perceptual assimilation task are typically presented in a confusion matrix showing the percentage assimilation of each L2 vowel to the closest L1 vowels (i.e., identification percentage of L2 stimuli in terms of L1 categories) and the median goodness of fit rating. An example is provided in Table 2. In order to take both measures into account, Guion et al. (2000)

Table 2: Example of confusion matrix showing PAT results (adapted from Cebrian et al. 2011). Each row shows the percentage assimilation of each L2 English stimulus to a L1 Catalan vowel. Goodness ratings are given in parentheses.

	English stimuli						
	/i	ɪ	eɪ	ɛ	æ	ʌ	ɜ/
i	96 (4.6)	82 (3.2)					
e		15 (3.4)		7 (3.3)			30 (2.0)
ei			90 (3.5)				
ɛ				91 (4.7)			24 (1.7)
a					100 (4.7)	85 (3.7)	23 (1.4)
ai		8 (2.7)					
ɔ						11 (4)	9 (2.7)

Figure 2: Example of Perceptual assimilation task. Display of response alternatives and rating scale.
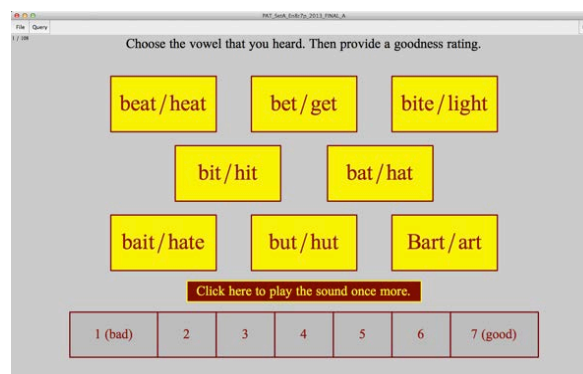
proposed a "fit index" score, calculated by multiplying the identification percentage by the median rating value.

PATs thus offer an appropriate means of providing perceptual similarity data. However, problems remain concerning the interpretation of the results (e.g. how high or low does a "fit index" need to be to consider a given L2 vowel a good or a poor match for an L1 vowel?), as well as concerning methodological issues such as the nature of the stimuli and the inclusion or exclusion of control L1 sounds.

The next sections explore different factors that may affect the outcome of perceptual similarity measurements. These can be grouped in terms of whether they concern the task itself and the type of stimuli used or if they involve individual differences concerning the listeners.

4. TASK FACTORS

4.1. Stimuli and other task design issues

Sounds are affected by their phonetic and prosodic contexts. This fact raises the question of whether the type of context in which target stimuli are presented in tasks like RDTs and PATs will have an effect on the similarity judgements. Strange, Bohn et al. (2004), Strange, Levy et al. (2004), and Strange et al. (2005) tested the perceptual similarity of North German

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vowels to American English vowels in different prosodic environments, namely words in citation form and longer words in carrier sentences. Although results were consistent in many cases, it was also found that prosodic context had an effect. For instance, when German /œ/ was presented in citation form, it was identified as an English back vowel 55% of the time and as an English front vowel 45% of the time. By contrast, when presented in a multisyllabic word embedded in a carrier sentence, the same vowel (German /œ/) was assimilated to an English back vowel 96% of the time.

The phonetic context, e.g., the nature of the segments preceding and / or following the target sound, has also been found to affect vowel assimilation patterns. Bohn & Steinlen (2003) found that Danish speakers assimilated English /i/ to Danish /e/ in glottal and alveolar contexts, but as /i/ in velar context. Further, Levy (2009) reported that assimilation patterns of French vowels to English vowels were more consistent in a bilabial context than in an alveolar context. In fact, discrepancies across studies testing the same population have been linked to the use of different phonetic contexts in different studies. Rallo Fabra (2005) and Rallo Fabra & Romero (2012) found that experienced Catalan learners of English identified English /ɪ/ mostly as Catalan /i/. By contrast, the experienced, and inexperienced, learners in Cebrian (2006) classified English /ɪ/ most frequently as Catalan /e/. Still, the studies differed in different ways. Stimuli in Rallo Fabra's studies involved sVt words, while Cebrian's stimuli consisted of vowels in isolation. Further, Rallo Fabra's stimuli were elicited from a dialectally non-homogeneous group of American English speakers, while the stimuli in Cebrian's study were produced by Canadian English speakers. Another methodological difference between the two studies was the fact that Rallo Fabra, but not Cebrian, included a "non-L1" response as a possible response alternative in the PAT, which was also chosen as a response for English /ɪ/.

Finally, studies examining perceptual similarity also differ in whether listeners are tested on non-native / L2 sounds only, or if L1 sounds are also included for comparison purposes. While the inclusion of L1 stimuli provides a useful baseline for native-like categorization, it also makes it possible for listeners to directly compare L1 and L2 sounds across trials, thus possibly interfering with the intended comparisons between the auditory stimuli and the listeners' internal mental representations.

In summary, different factors may affect the way non-native sounds are assimilated to native sounds, including the phonetic context, the prosodic context, the inclusion of control L1 stimuli in the task, the availability of a "none" response alternative or the type of native variety represented in the task.

## 5. LISTENER FACTORS

5.1. Amount of L2 experience

Strange (2007) argues that a complete analysis of cross-linguistic similarity should incorporate assessment of similarity by listener groups with different levels of L2 experience. Different studies have investigated if the perception of similarity between L1 and L2 sounds varies as a function of L2 experience. Recall that models like the Speech Learning Model (Flege, 1995, 2003) propose that learners need to discern differences between native and target-language sounds in order to establish authentic (target-like) categories for the L2 sounds. Flege claims that this ability is not lost as a result of maturation and that learners can eventually detect differences between native and non-native sounds given enough exposure to and experience with the target language. Few studies, however, have examined the effect of experience on cross-linguistic perception. Further, these studies have examined this issue by comparing two groups differing in experience, rather than investigating changes within the same population in a longitudinal approach.

Flege et al. (1994) tested Spanish speakers with different levels of L2 English proficiency by means of a rated dissimilarity task. They found that experience with English had little effect on the degree of perceived dissimilarity. Cebrian (2006) found that experience with the L2, understood as length of residence in the target language country, affected the identification of L1 vowels, but did not seem to affect the perception of similarity between L1 and L2 vowels. Further, Cebrian (2009) also found a fairly consistent pattern of English to Catalan vowel assimilation by two groups of Catalan speakers varying in amount of exposure to English from minimal exposure to several years of instruction.

Other studies have reported some effect of experience. Frieda & Nozawa (2007) compared the perceptual assimilation of English vowels to L1 Japanese vowels by two groups of Japanese L2 English speakers differing in level of proficiency. They found that the groups only differed in their assimilation of one of the English vowels, namely /ɪ/, showing some effect of experience, but experience did not affect the perception of the remaining vowels. Finally, Rallo Fabra (2005) and Rallo Fabra & Romero (2012) found differences in how experienced and inexperienced Catalan learners of English classified the English vowels /ɪ/ and /æ/. For instance, experienced learners tended to perceive English /ɪ/ as the L1 /i/, while the inexperienced learners classified it as the L1 /e/. Further, the experienced learners made a greater use of the "non-Catalan" response than the inexperienced group. These findings may indicate that experience may have enhanced the ability to distinguish L2 to sounds from L1 sounds, a prerequisite for more target-like L2 category formation according to most L2 speech models (e.g., Flege, 1995).

Possibly, in order to assess the effect of experience on the perceived similarity between native and

Figure 3: Visual display in an eye-tracking experiment (Cebrian & Mora, 2016).
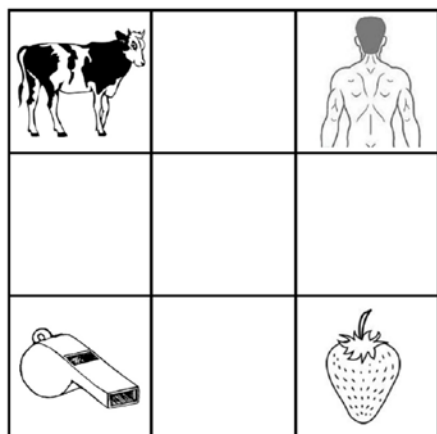
non-native sounds, a better approach would be a longitudinal study examining potential changes or developments in cross-linguistic perception by the same group of learners as a function of increased L2 experience.

5.2. Bidirectionality

Cross-language similarity studies typically test speakers of one of the two languages involved, namely speakers of the L1 in the study. Few studies have contrasted the same data from the point of view of both speakers of the L1 and of the L2. Some exceptions are Schmidt (1996, 2007) and Cebrian (2015). Schmidt tested the perception of a series of English and Korean consonants by native speakers of Korean and native speakers of English. Cebrian (2015) contrasted the results of RDTs involving pairs of English and Catalan vowels performed by native speakers of British English and native speakers of Catalan. In both cases, the researchers advocate for the contribution of bidirectionality as a more complete approach to measuring cross-linguistic similarity.

6. NON-PERCEPTUAL TASKS

As discussed in the previous sections, while perceptual measures are currently the most frequently used methods of assessing cross-linguistic similarity, there remain a number of practical and theoretical limitations. On the one hand, the inclusion of sufficient stimuli to obtain adequate data on which to base similarity judgements already renders perceptual tasks rather long and potentially tedious for the listeners. Further, the fact that the phonetic and the prosodic contexts affect the way sounds are perceived suggests that in order to obtain a reliable measure, multiple tasks would be needed, including different types of contexts and conditions. This would of course increase the length of tasks and the probable fatigue effects. On the other hand, identification and dissimilarity ratings tasks are tasks that require the listener to reflect on the stimuli provided and pass a judgement. Such off-line tasks do not reflect the way that sounds are processed in real-life speech perception or in every-day

conversations. An alternative approach would be one involving online tasks of the sort that are used in language processing research.

6.1. On-line tasks and language processing

There is evidence that L2 speakers access both L1 and L2 lexicons when processing L2 speech (Chambers & Cooke, 2009; Marian & Spivey, 2003, among others). This evidence comes from eye-tracking studies in which participants follow instructions to click on a depicted target word, presented alongside a phonological competitor and two distractors. Using this methodology, for instance, Marian & Spivey (2003) found that in the course of processing the English word *marker* (target word), Russian speakers of L2 English would look to a picture of a stamp (Russian "marku", phonological competitor from the L1) more often than to pictures of phonologically unrelated words (distractors). This indicates that when processing a given L2 word, speakers activate similar sounding L1 words, at least temporarily. Following these findings, Cebrian & Mora (2016) explored the use of such online tasks to measure phonetic or perceived similarity between L1 and L2 sounds. For instance, in order to explore the phonetic similarity between English /æ/ or /ʌ/ and Spanish or Catalan /a/, crucial trials included an English word containing each of these vowels and another word whose translation into the L1 contains vowel /a/.

One example is given in Figure 3, from Cebrian and Mora (2016). In this case, the target word is *back* (/bæk/) and the interlingual competitor is *cow* (Spanish and Catalan *vaca*, whose first three sounds are /bak-/). The other two pictures in the display show unrelated distractors. Eye gazes to the interlingual competitor (vaca) are measured as the participant hears and processes the instructions to *click on the back*. Comparing the results for this type of trial with trials involving /ʌ/ as the target vowel (e.g., target *buck* and competitor *vaca*) would provide an online measure of which of the two English vowels, /æ/ or /ʌ/, trigger more looks to the interlingual competitor (/a/).

In fact, preliminary results reported by Cebrian and Mora (2016) show a close link between PAT results and the results of an online task. The results of the PAT showed that Catalan /a/ is closer to English /æ/ than to English /ʌ/. This result went hand in hand with the finding that greater L1 competition was observed from Catalan /a/ when the target word contained English /æ/ than when it contained English /ʌ/. Online tasks thus emerge as a potentially effective method to assess crosslinguistic similarity.

7. SUMMARY AND CONCLUSIONS

This paper has reviewed the importance of assessing the phonetic similarity between native and non-native sounds in order to make appropriate predictions about the learnability of L2 sounds. The main methodological approaches have been discussed, with an emphasis on perceptual methods of assessment such as rated

dissimilarity tasks and perceptual assimilation tasks. Despite being the most reliable method of measuring cross-language similarity, perceptual tasks still face a number of limitations including the need to control and incorporate the effects of phonetic and prosodic contexts and their relative length and potential fatigue effects. Online tasks used in language processing offer new alternatives to the assessment of cross-linguistic similarity.

8.   ACKNOWLEDGMENTS

9.   REFERENCES

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