The Processing of Lexicon and Morphosyntax

The Processing of Lexicon and Morphosyntax

Edited by

Vincent Torrens and Linda Escobar

CAMBRIDGE SCHOLARS
PUBLISHING

The Processing of Lexicon and Morphosyntax,
Edited by Vincent Torrens and Linda Escobar

This book first published 2014

Cambridge Scholars Publishing

12 Back Chapman Street, Newcastle upon Tyne, NE6 2XX, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-4438-5711-4, ISBN (13): 978-1-4438-5711-6

TABLE OF CONTENTS

AN OVERVIEW OF LANGUAGE PROCESSING

VINCENT TORRENS AND LINDA ESCOBAR

It is well known that research on cognitive development is very wide; in order to narrow this subject matter, this book intends to contribute to a general interest by highlighting recent research on speech perception and production concentrating on two key areas: lexical and sentence processing. Among others, we cover some crucial topics of word learning, the tip-of-the-tongue phenomenon, lexical access and metaphors in the arena of first language acquisition, foreign language learning and speech processing. [1]

In contrast to most books dealing with research on cognitive studies, this book is an attempt to provide an overview from the combination of the perspective of both psycholinguists and linguists. The reader will find the scientific method by which certain hypotheses are tested by online experimental methods, self-paced reading, semantic priming and event related potentials. In addition, the results will also be interpreted taking into account some linguistic approaches to sentence processing. The first area covered in the book deals with the crucial topics of word learning, the tip-of-the-tongue phenomenon, lexical access and metaphors. The second area concerns the intricate question of whether syntactic properties of different languages affect language processing looking at evidence of different linguistic phenomena such as verbal aspect, logical form, quantifiers, argument structure and movement.

The first paper by Barcroft & Sommers reviews research on how acoustically varied input affects speech processing in L1. In addition it

[1] This volume includes a selection of the papers presented at the Experimental Psycholinguistics Conference that took place in Madrid with the aim to include a large number of studies conducting research in the field of psycholinguistics. The editors of this volume would like to thank the help of the members of the scientific committee: Vasiliki Chondrogianni, Nina Kazanina, Victoria Marrero, Robert Reichle, Eva Soroli and Monica Wagner. They are also grateful to Albert Costa, Conxita Lleó and Frank Wijnen for their participation in the conference organised thanks to the financial support of the Universidad Nacional de Educación a Distancia.

analyses new word learning in both L1 and L2 in order to draw conclusions about the effects of acoustic variability in the evolving quality of lexical representations. They consider how word identification in L1 English is negatively affected by phonetically relevant sources of variability such as talker, speaking style, and speaking rate but not by amplitude and fundamental frequency. They also explain how these five sources of variability affect new word learning, by showing how phonetically relevant sources that pose costs to L1 word identification also positively affect new word learning whereas amplitude and fundamental frequency yield null effects in both domains.

Bordag, Kirschenbaum, Opitz & Tschirner, next, present a study on the incidental vocabulary acquisition during reading of syntactically complex and simple texts by adult native speakers of German. A comparison of the L1 data with the L2 data reveals that syntactic complexity positively affects L2 acquisition of new meanings, but does not influence acquisition while reading in L1. The results further indicate that while new lexical units are added to the open, incomplete L2 system with relative ease, adding new items to the L1 lexicon is more restricted. While the L2 data show evidence of an interaction of newly acquired meanings with earlier acquired representations, no evidence for such integration into the semantic network can be found for the L1 data. The results suggest that new L1 representations are stored in episodic memory rather than in semantic memory.

Cherepovskaia & Slioussar, then, study which mechanisms are involved in understanding metaphors in online processing. These authors attempt to shed new light on the question whether metaphors are more difficult to process than literal expressions. In order to do so, they choose syntactically diverse materials in Russian to replicate previous studies analyzing how two types of metaphors are processed in comparison with the same expressions of literal meanings. They argue that the first type of metaphor is engrained in the speakers' minds on the conceptual level, but can be expressed in different ways. In contrast, the second type of metaphor turns out to be fixed both on the conceptual and on the linguistic level. Their findings also show that metaphors in these two groups are processed differently. Yet, they do not find any evidence that literal meaning is assessed first. However they conclude that unlike the first type of metaphor, the second type is stored in the mental lexicon as a whole.

The paper that ends the first part of the book by Hofferberth & Abrams presents a study on Tip-of-the-tongue phenomenon (TOT). They support the idea that TOT represents a speaker's temporary and typically frustrating inability to retrieve a known word, which results from weakened connections between a word's lexical representation (lemma) and its phonology (lexeme). They also argue that encountering phonologically-related cues during a TOT specifically related to words containing the first syllable helps to resolve such an inability. The chapter then discusses different models of speech production where the locus of TOT is found using various methodologies investigating TOT states in laboratory studies, including a new experiment using a syllable in isolation as the cue.

The second part of the book starts with Błaszczak, Jabłońska & Klimek-Jankowska's chapter concerning one of the most contentious issues in new psycholinguistics ERP experiments about the P600 index related to the interpretation difficulty reflecting both semantic and syntactic integration problems. The goal of this paper is "to report new psycholinguistic (*Event Related Potentials*, ERP) results related to the processing of grammatical aspect in converbial contexts in Polish", given the case that "Polish converbs (gerunds) impose two kinds of restrictions: (i) specific morphological selectional requirements as well as (ii) specific semantic/pragmatic constraints on temporal ordering." The authors test different morphological mismatches in contexts of selectional restrictions imposed by anteriority and simultaneity converbial morphemes on their verbal stems. On the standard assumption that a P600 value reflects an integration difficulty at the morpho-syntactic level, the authors discuss the experimental question, among others, "why the P600 is stronger in the case of simultaneous ungrammatical converbs".

The study presented by Marcilese & dos Santos Rodrigues explores in detail how Brazilian Portuguese adults interpret distributive and collective readings when the universal quantifier "todo" is in play. These authors use online methodology to provide evidence in favor of the *Good enough* approach according to which the language processor can sometimes generate only partial, incomplete representations of the linguistic input (Christianson et al. 2001; Ferreira and Stacey 2000; Ferreira 2002; Ferreira and Patsos 2007). These authors make use of online methodology *Psyscope*, and according to their results, they further claim that differently from language production, comprehension seems to be strongly influenced by a "fast problem-solving" principle. These authors suggest that theoretical semantic and syntactic descriptions of linguistic phenomena do not necessarily explain the effects observed during language processing.

The last two chapters by Martínez-Ferreiro and by Thompson & Enzinna explore in detail how processing relates to syntactic derivations in the case of argument structure and movement. Their conclusions are, however, very different. Martínez-Ferreiro put forward "the crucial role of argument structure, and, more specifically, the relative complexity of unaccusative verbs in comparison to unergative forms in developmental dyslexia along with non-brain-damaged subjects", whereas Thompson & Enzinna conclude that processing seems not to be affected by the same syntactic constraints that are present in sentence derivations. In particular, the Minimal Structure Principle (MSP) by which the representation with more projections is discriminated in favor of the one with fewer ones is claimed not to be active in language processing. As evidence, they show that "P-Stranding and Pied-Piped Sentences in general have similar processing costs" despite the fact that the former derivation has less projections than the latter ones.

In sum, both parts in this book attempt to cover most of the core concerns of psycholinguistics considering lexical and sentence processing and its implications for syntactic assumptions, while keeping the reader interested in new methodological approaches and new paradigms from experimental psycholinguistics, neuroscience and cognitive psychology. Moreover, most chapters do not only focus on empirically-driven theory advancement, but also on the impact of these advancements in applied contexts such as first language acquisition, foreign language learning and speech processing,

PART I.

LEXICAL PROCESSING

A THEORETICAL ACCOUNT OF THE EFFECTS OF ACOUSTIC VARIABILITY ON WORD LEARNING AND SPEECH PROCESSING

JOE BARCROFT AND MITCHELL S. SOMMERS[1]

Abstract

In this paper we review research on how acoustically varied input affects speech processing in a first language (L1) and new word learning (in both L1 and second language, L2) in order to draw conclusions about the effects of acoustic variability on the evolving quality of lexical representations. First, we consider how word identification in L1 English is negatively affected by phonetically relevant sources of variability such as talker, speaking style, and speaking rate but not by amplitude and fundamental frequency (F0) (Mullennix, Pisoni & Martin, 1989; Sommers, Nygaard & Pisoni, 1994; Sommers & Barcroft, 2006). Second, we explain how these five sources of variability affect new word learning (in L2, Barcroft & Sommers, 2005; Sommers & Barcroft, 2007; Sommers; and for talker variability, in L1, Sommers, Barcroft & Mulqueeny, 2008). Those phonetically relevant sources that pose costs to L1 word identification also positively affect new word learning whereas amplitude and F0 yield null effects in both domains. Finally, we present a model of how phonetically relevant acoustic variability affects lexical acquisition and speech

[1] Joe Barcroft
Department of Romance Languages and Literatures
Washington University in St. Louis
St. Louis, MO 63130
E-mail: barcroft@wustl.edu

Mitchell S. Sommers
Department of Psychology
Washington University in St. Louis
St. Louis, MO 63130-4899
E-mail: msommers@wustl.edu

processing across the lifespan. It depicts how phonetically relevant variability (a) positively affects new word learning by producing more distributed lexical representations and (b) poses costs during lexical processing because variant forms must be mapped onto the canonical word forms.

1. Background

Acoustic variability refers to variations in dimensions of the speech signal other than the specific linguistic content. For example, the same linguistic information can be spoken by different talkers or at different speaking rates, resulting in what Pisoni (1985) has termed variations in indexical, as opposed to linguistic, features of speech. In this paper, we consider the role of acoustic variability across the lifespan by reviewing research findings on the effects of different sources of acoustic variability-talker, speaking style, speaking rate, amplitude, and fundamental frequency-in two areas: (a) first language (L1) speech processing and (b) second language (L2) and L1 vocabulary learning. After identifying the unique pattern of research findings that has emerged within these two areas of research, we propose a model that depicts cognitive responses related to vocabulary learning and speech processing when one is exposed to input that contains phonetically relevant acoustic variability over time.

In the research review in this section we first consider effects of five sources of variability-talker, speaking style, speaking rate, amplitude, and fundamental frequency-on L1 speech processing. We do so while paying particular attention to studies on word identification in noise wherein target words are presented in acoustically consistent versus acoustically varied formats. We then move on to studies on the effects of the same five sources of variability on L2 vocabulary learning and, in one case, the effects of talker variability on L1 vocabulary learning. This organizational structure is largely historical in nature given that much (but not all) of the research on acoustic variability and L1 speech processing preceded the research on acoustic variability and L2 vocabulary learning. However, once the research review is complete and the intriguing pattern of findings is summarized, we transition to a more developmental perspective when presenting our model of the relationship between acoustic vocabulary, vocabulary learning, and speech processing across the lifespan given that learning a word precedes the ability to identify that word in noise from a developmental perspective.[2]

---

[2] Whereas this review focuses on effects of acoustic variability on speech

2. Previous studies on speech processing and vocabulary learning

2.1. Research on Acoustic Variability and Speech Processing

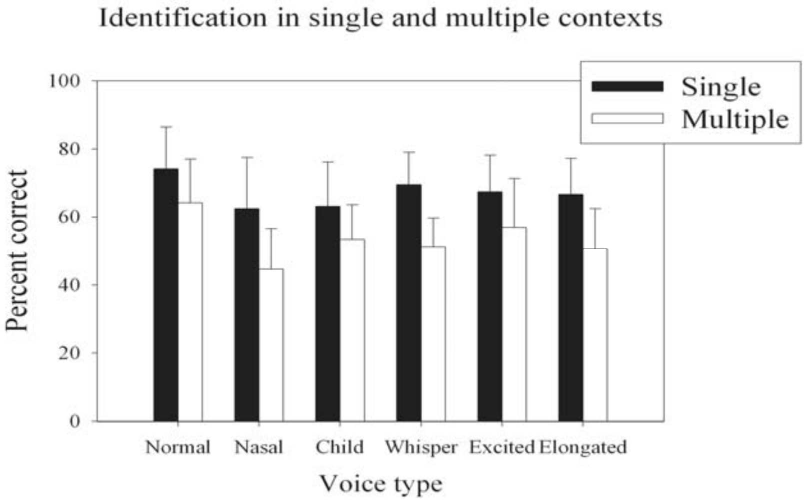
Many studies on acoustic variability and L1 speech processing point to the cognitive costs of processing acoustically varied as opposed to acoustically consistent stimuli. For example, presenting tokens produced by multiple as opposed to single talkers decreases L1 vowel perception (Assmann, Nearey & Hogan, 1982), word recognition (Mullennix, Pisoni & Martin, 1989; Ryalls & Pisoni, 1997; see also Creelman, 1957; Peters, 1955, as cited in Pisoni, 1997), and word naming (Mullennix, Pisoni & Martin, 1989).[3] In addition, Sommers and Barcroft (2006, Experiment 1) found that word identification in L1 was negatively affected by speaking-style variability. In this case, the no-variability condition involved listening to target words in one of the six speaking styles (produced by a single talker): normal, excited, denasalized, elongated (produced at a slow speaking rate), child-like (talker was asked to produce items "as if speaking like a young child"), and whispered voices. The variability condition, in contrast, involved listening to target words in all six of these speaking styles. The results of that study can be seen in Figure 1. Sommers, Nygaard, and Pisoni (1994) and Sommers and Barcroft (2006, Experiment 3) also demonstrated negative effects for speaking-rate variability. All of these findings are consistent with the position that listeners process indexical features of input containing talker, speaking-style, and speaking-rate variability, which poses a cost that increases the overall needed for L1 word identification.

---

processing and vocabulary learning, key findings in other areas, such as research on the effects of talker variability on memory for L1 words and L2 phonemic training, also will be briefly noted.

[3] There is also evidence indicating that at least some types of acoustic variability can improve memory for L1 words. Mullennix, Pisoni, and Martin (1989) found that memory for words spoken by multiple talkers was significantly better than memory for words spoken by only a single talker. Similarly, Goldinger, Pisoni and Logan (1991) found that, when listeners are given sufficient time to encode voice characteristics, serial recall is better for items spoken by multiple than single talkers. Thus, acoustic variability is associated with both costs and benefits in L1. The costs are reflected in reduced speech intelligibility for acoustically varied input; the benefits are reflected in improved memory for items produced with variable acoustic features.

Figure 1. Effects of speaking-style (voice-type) variability on spoken word identification in L1



Not all sources of variability have been found to produce negative effects on L1 word identification, however. Sommers, Nygaard, and Pisoni (1994) assessed the effects of overall amplitude and found that it had little effect on L1 word identification. They explained this finding by proposing that only sources of variability relevant to phonetic perception will impair spoken word identification. According to this phonetic relevance hypothesis, variability in overall amplitude, in contrast to talker, does not alter acoustic properties that are used for phonetic perception (in this case for speakers of English) and therefore does not pose the cost to L1 word identification that talker does. Sommers and Barcroft (2006, Experiment 2) corroborated this position by demonstrating that variability in overall fundamental frequency (F0), argued not to alter significantly the acoustic properties used for phonetic perception for speakers of English (in contrast to what would be the case for speakers of tone languages), also produced null effects on L1 word identification performance.

To summarize, three sources of variability -talker, speaking style, and speaking rate- have been found to produce negative effects on spoken word identification whereas two sources of variability -amplitude and F0- have not, at least for L1 speakers of English. According to the phonetic relevance hypothesis proposed by Sommers, Nygaard, and Pisoni, this pattern of findings makes sense because talker, speaking-style, and speaking-rate variability alter phonetically relevant properties within the speech stream whereas amplitude and F0 variability do not, at least for speakers of English. Clearly, it would be worthwhile to examine other sources of acoustic variability and to examine the effects of overall F0 variability on word identification performance with participants who speak a tone language and, therefore, for whom F0 is phonetically relevant at the lexical level. In such a case, one might predict negative effects, in contrast to the null effects observed for F0 variability among speakers of English.

2.2. Research on Acoustic Variability and Vocabulary Learning

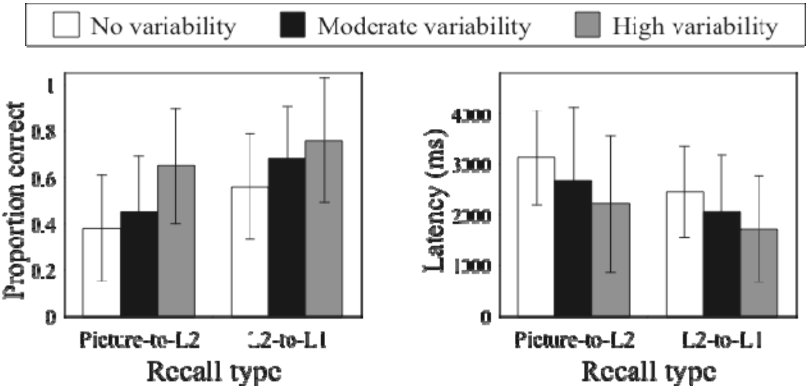
The same five sources of variability (talker, speaking style, speaking rate, amplitude, and F0) that have been tested with regard to their effects on spoken word identification in L1 have been assessed with regard to their effects on L2 vocabulary learning (Barcroft & Sommers, 2005; Sommers & Barcroft, 2007; Barcroft & Sommers, accepted pending revisions), and in the case of talker variability, with regard to their effects on L1 vocabulary learning (Sommers, Barcroft & Mulqueeny, 2008). Does processing indexical properties of input with phonetically relevant acoustic variability lead to more distributed lexical representations of word form and in this way positively affect vocabulary learning? If so, is this benefit restricted to sources of variability that are phonetically relevant to the participants attempting to learn the new vocabulary? In this section, we review the studies that were designed to address these questions.[4]

To begin, Barcroft and Sommers (2005) examined the effects of variability in speaking style (voice type) and talker on naïve listeners' ability to learn Spanish (L2) vocabulary. Speaking style and talker were selected as sources of variability because they represent one instance of intraspeaker variability (speaking style) and once instance of interspeaker variability (talker) that occur naturally. The general methodology used in

[4] Another body of research suggests that acoustically varied presentation formats can be useful when teaching L2 phonemic contrasts, such as when training native Japanese speakers on the English contrast between liquid consonants /r/ and /l/. A number of studies have found benefits of acoustically varied input when training on this contrast (Logan, Lively, & Pisoni, 1991; Lively, Logan, Pisoni, 1993; Lively, Pisoni, Yamada, Tokura, et al., 1994; Bradlow, Pisoni, Akahane-Yamada & Tokura, 1997; see also Hardison, 2003). These findings suggest that access to indexical features of speech can facilitate establishing phonemic categories. According to Logan, Lively, and Pisoni, the use of acoustic variability during training may help listeners develop "stable and robust phonetic categories that show perceptual constancy across different environments" (p. 876).

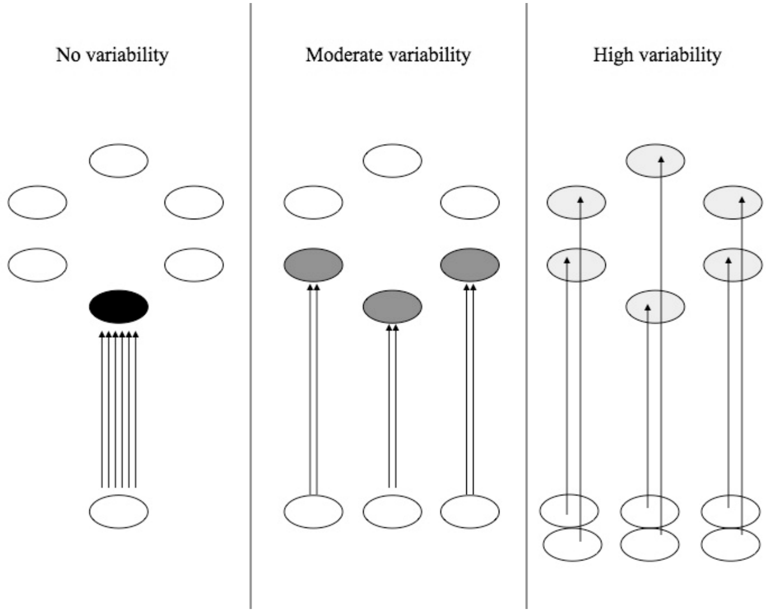
these experiments was to compare vocabulary learning in conditions with no variability (one talker or one speaking style), moderate variability (3 talkers or 3 speaking styles) and high variability (6 talkers or 6 speaking styles). For both sources of variability, speed and accuracy of picture-to-L2 recall and L2-to-L1 translation were the dependent measures. The findings for both sources of variability indicated positive and additive effects for acoustic variability. The participants were faster and more accurate in both types of recall when they learned the words in acoustically varied as compared to acoustically consistent formats. Moreover, learning with high variability was better (faster and more accurate) than for moderate variability, which in turn was better than with no variability. The results for talker variability can be seen in Figure 2.

Figure 2. Effects of talker variability on L2 vocabulary learning



The researcher attributed this pattern of findings to the encoding of indexical features with the novel word forms during each presentation of a target word, which leads to a more distributed (robust) developing representation of the word forms in question. A model of this process appears in Figure 3.

Figure 3. Model of the positive effects of variability on developing lexical representations



In another study, Sommers and Barcroft (2007) assessed boundary conditions for the benefits of variability by looking at the effects of three different sources of acoustic variability -overall amplitude, fundamental frequency, and speaking rate- on L2 vocabulary learning. Sommers and Barcroft hypothesized that overall amplitude and fundamental frequency might not affect L2 vocabulary learning in consideration of the phonetic relevance hypothesis and its predictions regarding L1 spoken word performance (Sommers, Nygaard & Pisoni, 1994) and the lack of effect of amplitude and F0 variability previously observed by Sommers, Nygaard, and Pisoni and Sommers and Barcroft (2006), respectively. Recall that, according to the phonetic relevance hypothesis, listeners encode and retain indexical properties of the speech signal such as talker characteristics and speaking rate that affect acoustic features, such as formant frequencies and transitions, that are used for phonetic identification whereas sources that do not alter phonetically relevant features, such as overall amplitude (affecting perceived loudness without altering formant frequencies or other phonetically relevant parameters), are ignored or processed more automatically (as in the case of an automatic gain control).

In applying the phonetic relevance hypothesis to studies of acoustic variability and L2 vocabulary learning, Sommers and Barcroft (2007) reasoned that if the beneficial effects of talker and speaking-style variability are a result of encoding and retaining phonetically relevant sources of variability (i.e. they serve as an additional retrieval cue), then sources of variability that are not retained (because they are not phonetically relevant for single-word stimuli among English speakers, as was the case in the study) should not provide a benefit in recall performance. Consistent with this prediction, Sommers and Barcroft found that neither variability in overall amplitude nor in fundamental frequency affected L2 vocabulary learning as measured by the same dependent variables used by Barcroft and Sommers (2005). Speaking-rate variability, on the other hand, produced positive effects, which is also consistent with the phonetic relevance hypothesis and Barcroft and Sommers (2005) explanation of how processing of indexical information in acoustically varied speech can lead to more distributed developing representations of novel word forms and in this way improve L2 vocabulary learning.

Sommers and Barcroft (2007) proposed the extended phonetic relevance hypothesis to explain this pattern of effects observed for different sources of acoustic variability and L2 vocabulary learning. According to this hypothesis, English speakers benefit from speaker, speaking-style, and rate variability because these sources of variability are phonetically relevant (indexical properties of speech that affect acoustic features, such as formant frequencies and transitions, which are used for phonetic identification) to them. They do not benefit, however, from amplitude variability and FO variability, at least in the case of English speakers, because these sources of variability are not phonetically relevant to them.

Sommers, Barcroft, and Mulqueeny (2008) assessed whether the benefits of talker variability would extend to (a) L2 words in another L2, Russian (Experiment 1); (b) novel words (pseudowords) that represented known objects versus novel objects (nonobjects) (Experiment 2); and (c) L1 words, in this case very low frequency concrete nouns so that they would be novel to adults (Experiment 3). In all three experiments, the participants were native speakers of English. They attempted to learn 8 new words in conditions of no variability (1 talker), moderate variability (3 talkers), and high variability (6 talkers). In all three experiments, positive and additive effects of talker variability were observed for accuracy and latency of vocabulary recall, suggesting that the benefits of acoustic variability extend to multiple types of vocabulary learning in both L1 and L2.

Barcroft and Sommers (2011) helped to isolate the causal mechanism of the benefits of acoustic variability by assessing whether the benefit is due to difficult encoding demands (cognitive effort hypothesis) or the development of a more distributed (robust) developing lexical representation. Experiment 1 in the study compared the effects of learning new words in normal (easier encoding) versus denasalized (more difficult encoding) voice. The normal-voice condition led to more vocabulary learning, providing direct evidence against the cognitive effort hypothesis. The second experiment assessed the robustness of the lexical representations of words learned in acoustically consistent versus acoustically varied formats by measuring the accuracy and latency of L2-to-L1 translation at four different signal-to-noise ratios. At all four ratios, words learned in the acoustically varied condition produced better (more accurate and faster) performance, and the degree of improved performance of the single- over multiple-talker condition increased as a function of the amount of decrease in the signal-to-noise ratio. These findings, which are consistent with the representation quality hypothesis and inconsistent with the cognitive effort hypothesis, provide strong evidence that the positive effects of phonetically relevant sources of acoustic variability such as talker are not due to increased cognitive effort but are the result of phonetically relevant acoustic variability promoting more robust formal representations for the target words in question.

In another study, Barcroft and Sommers (accepted pending revisions) sought to test the extended phonetic relevance hypothesis (as described above) by examining effects of overall F0 variability among (a) bilingual speakers of Zapotec (a tone language) and Spanish, for whom overall F0 should be phonetically relevant at the lexical level due to their knowledge of Zapotec, and (b) speakers of Spanish who did not speak a tone language, for whom overall F0 should not be phonetically relevant at the lexical level. All participants attempted to learn 24 Russian concrete nouns while hearing words and viewing pictures on a computer screen. Three levels of F0 variability were compared: (a) no variability, or 1 F0 for 6 repetitions of a word; (b) moderate variability, 3 F0s x 2 repetitions; or (c) high variability, or 6 F0s x 1 repetition. The specific F0 levels used in the no variability condition were counterbalanced across participants. The results indicated that F0 variability significantly improved L2 vocabulary learning for speakers of the tone language (Zapotec) but not for the others, for whom null effects were obtained. These findings provided strong new evidence favoring the predictions of the extended phonetic relevance hypothesis.

To summarize, research on acoustic variability and vocabulary learning has demonstrated positive and additive effects for acoustic variability when the sources of variability in question are phonetically relevant to those learning new vocabulary, including the sources talker, speaking style, speaking rate, and, in the case of tone language speakers only, F0. Acoustic variability based on sources that are not phonetically relevant to those learning the new vocabulary produce null effects. Examples of these sources are amplitude and F0 variability for speakers of English and Spanish learning novel vocabulary, but not in the case of F0 variability for speakers of a tone language (Zapotec). Other findings, such as those of Sommers and Barcroft (2011), strongly support the position, as proposed by Barcroft (2005), that at least some sources of acoustic variability lead to more distributed (robust) representations of the novel words being studied.

3. Theoretical proposals

3.1. A Unique Pattern of Effects for Different Sources of Variability

As can be viewed clearly in Table 1, an interesting pattern has emerged with regard to the effects of different sources of variability on L1 word identification and L2 vocabulary learning. The sources of variability that decrease L1 word identification performance are the same as those which produce positive effects on L2 vocabulary learning, and L1 vocabulary learning in the case of talker. As can be seen in the bottom two rows, establishing phonetic relevance depends on the previous linguistic experience of an individual. Whereas for tone language speakers overall F0 is phonetically relevant, for non-tone language speakers, it is not, at least at the lexical level when it comes to contrasting between minimal pairs, such as the contrast between /ɾùtʃàː/ meaning ‘change’ and /ɾùtʃǎː/ (the second syllable having a rising tone) meaning ‘reheat’ in Isthmus Zapotec.

The question mark in the table indicates research still needing to be conducted on the effects of F0 variability on spoken word identification in L1 among speakers of a tone language. Both the original and extended versions of the phonetic relevance hypothesis would predict that F0 variability should increase processing time (increase reaction times) during word identification among this group of speakers. Additionally, given that the positive effects of phonetically relevant acoustic variability on vocabulary learning have only been demonstrated once for talker variability only, future research should examine the effects of other sources of variability on L1 vocabulary in order to determine whether the pattern of effects in L1 follows the pattern that has been demonstrated for L2 vocabulary learning.

Table 1: Effects for Different Sources of Variability on L1 Word Identification and L2 Word Learning

Source of Variability	Phonetically Relevant?	L1 Word Identification	L2 Word Learning
Talker	Yes	Negative[1]	Positive[5]
Speaking Style	Yes	Negative[2]	Positive[5]
Speaking Rate	Yes	Negative[3]	Positive[6]
Amplitude	No	Null[2]	Null[6]
F0 for tone language speakers	Yes	?	Positive[7]
F0 for non-tone language speakers	No	Null[4]	Null[6,7]

[1]Mullennix et al. (1989); [2]Sommers & Barcroft (2006); [3]Sommers, Nygaard & Pisoni (1994); Sommers & Barcroft (2006); [4]Barcroft & Sommers (2006), [5]Barcroft & Sommers (2005); also Sommers, Barcroft, & Mulqueeny, 2008 for talker and L1 vocabulary learning; [6]Sommers & Barcroft (2007); [7]Barcroft & Sommers (accepted pending revisions)

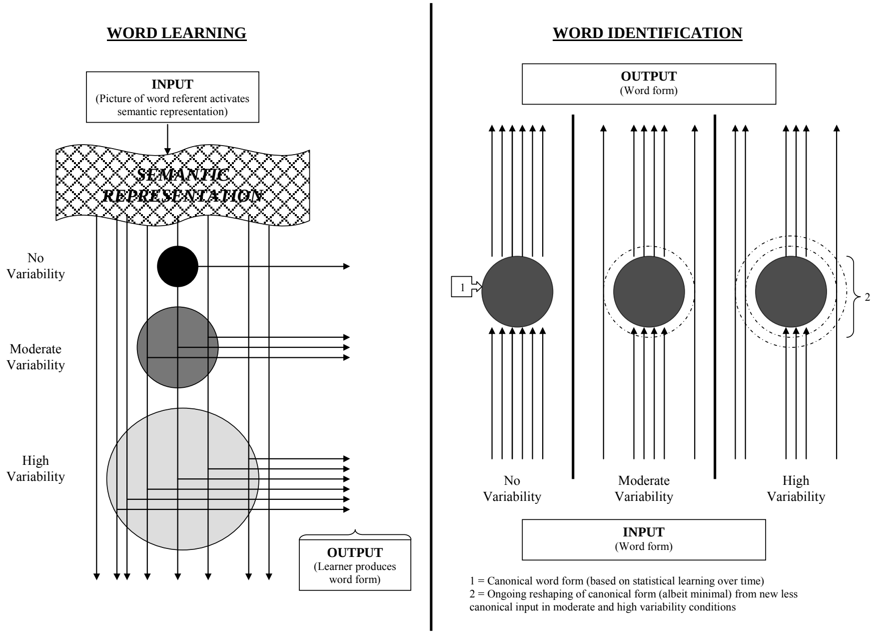
What does the pattern of effects depicted in Table 1 mean when it comes to the effects of acoustic variability across the lifespan? First, it clearly means that not all types of acoustic variability are alike and cannot be expected to produce the same effects. Whereas talker, speaking-style, and speaking-rate variability can be expected to produce negative effects (increased reaction time) on spoken word identification and positive effects on vocabulary learning (in L2 and in L2, at least for talker variability), amplitude and F0 variability can be expect to have no significant effect on either word identification or vocabulary learning. These findings are consistent with the extended phonetic relevance hypothesis. Second, the pattern of effects also indicates that not it clearly means that not all speakers should be expected to respond in the same manner to different sources of acoustic variability. As the bottom two rows in Table 1 illustrate, speakers experienced with using tonal contrasts at the lexical level experience benefit from F0 variability when attempting to novel vocabulary whereas speakers who are not experienced in using tonal contrasts in this manner do not benefit from F0 variability. Finally, the pattern of effects points to the need for a theoretical explanation of the effects of phonetically relevant acoustic variability at different stages of linguistic development and language use. Why is it that acoustically relevant acoustic variability has positive effects on vocabulary learning, increasing accuracy and shortening response times, but poses costs during spoken word identification, increasing response times? The model proposed in the following section was designed to address this critical question.

3.2. Modeling the Effects of Phonetically Relevant Acoustic Variability across the Lifespan

In this final section, we present a model (Figure 4) designed to account for why phonetically relevant acoustic variability at once positively affects vocabulary learning (increasing accuracy and decreasing response times) and negatively affects L1 speech processing (increasing response times on spoken word identification). The model assumes that the type of acoustic variability being provided in the input is phonetically relevant to the listener(s) in question, which implies the listener(s) will process the acoustically varied input (and not simply ignore or gain-control it out) in a manner that allows for the indexical information in the acoustically varied input to be encoded and stored.

The three circles on the left side of the model (Word Learning) represent the degree to which the formal component of a developing lexical representation is distributed or robust (see Figure 3 for a depiction of how increases in variability can lead to more distributed representations). Therefore, what is depicted here is how the more distributed (robust) representations associated with having processed acoustically varied input leads to better cued recall of target words. In essence, the left side of the model is depicting what happens during a posttest phase when a participant is presented with a picture and is asked to attempt to retrieve the target word in question. In such a case, the input consists of a picture, which in turn activates the semantic representation for the referent in question (as represented by the arrow from the input box to the semantic representation box. Because the semantic representation is distributed (such as when the semantic space after seeing a picture of a squirrel is activated), the nature of the “search” for the appropriate novel form (such as ardilla, the Spanish word for 'squirrel') is also distributed in nature, as depicted by the downward stream of six lines, which are not uniformly spread across the semantic representation box.

Figure 4. Model of the positive and negative effects of phonetically relevant acoustic variability across the lifespan



At this point we can observe why the more distributed representations of words learned with more variability are more likely to be retrieved when cued by a picture. The reason is that the more distributed representations are more likely to come into contact with the "search" lines emanating from (or simply being part of) the semantic representation. As can be seen in the model, a word learned with no variability makes contact only once, whereas a word learned with moderate variability makes contact three times, and a word learned with high variability makes contact six times. Each contact constitutes a successful meaning-to-form mapping and allows the participant to produce the recently learned (or being learned) word form in question. Therefore, as indicated by the larger number of arrows in the output for high variability (six arrows) over moderate (three arrows) and low variability (one arrow) and the larger number of arrows in the output for moderate over no variability, the developing representation of word forms learned in more acoustically varied formats (as more acoustically varied input) is naturally retrieved more often, allowing them to be produced more often as output.

The right side of the model, on the other hand, depicts the effects of phonetically relevant acoustic variability on word identification and the continuing development of the formal component of lexical representations. In contrast to the left side of the model, the right side concerns cognitive procedures that happen long after the word to be identified has been learned. Input is depicted on the bottom, and output on the top as it was deemed easier to follow visually in this manner, but it would make no difference if the two were inverted, providing that the arrows always go from input toward output. The three circles represent the canonical representation of the form of any given word. The lines going upward represent instances of the word form in question being produced in spoken input. Instances in which an upward-moving line makes contact with the solid part of the circle represent instances in which a word is accurately perceived and identified.

The degree to which the upward-moving lines are spread apart represents the degree to which the listener is being exposed to acoustically varied spoken input. In the case of no variability, the lines are close together, depicting the lack of variability in the input to which the listener is exposed. In this case, all six lines make contact with the solid circle and therefore are successfully retrieved and identified. In the case of moderate variability, the lines are not as close together, representing more acoustically varied input, and two of the lines do not make contact with the solid circle, leading to less accurate retrieval and worse word identification. Finally, in the case of high variability, the lines are even more spread apart, representing even more acoustically varied input, and three of the lines do not make contact with the solid circle, leading to even less accurate retrieval and even worse word identification. In this way the model depicts why phonetically relevant acoustic variability leads to worse performance on spoken word identification.

In light of the fact that language users are also language learners, the model also depicts how acoustically varied input for words, even when they were first learned a long time ago, has an impact upon their canonical formal representations. The three solid circles represent the canonical form of a word. When listeners are presented with acoustically varied input that does not match this existing canonical form, the canonical form reshapes in response to the noncanonical forms to which the listener (listener-learner) has been exposed. The dotted circles represent this reshaping. As can be seen in the model, assuming that input without acoustic variability is consistent with the existing canonical form, no reshaping will take place. Moderately variable input, on the other hand, can cause the canonical form to reshape to a certain degree, as represented by the single dotted circle around the solid circle. Finally, highly variable input can cause the canonical form to reshape even further, as represented but the two dotted circles.

Of course we are assuming a distributed representation of word form in both the word-learning and word-identification sides of the model, therefore, the size of the circles on the word-identification simply represent that a certain degree of reshaping will take place in this distributed representation of the word form in question. The reshaping may be very minor in some cases, but in other cases it may be more substantial, such as in cases when one is exposed to a new variety (dialect) of their native language over an extended period of time and the process of accommodation begins to take place.

One of the strengths of the model presented here is that it provides a mechanistic account of the effects of phonetically relevant acoustic variability across the lifespan, beginning with how it affects vocabulary learning when we are first exposed to new lexical items and extending to how it affects how we process speech during word identification. The more distributed lexical representations associated with acoustically varied input during vocabulary learning depict why more instances of target word form can be retrieved when cued by the activation of the conceptual/semantic space of the referent of the target word in question. The lack of one-to-one mapping of acoustically varied forms of a known (previously acquired) word and the canonical form of the word depict why acoustically varied input poses costs during word identification. Clearly, future work can help to provide more fine-grain accounts of the processes involved in both word learning and word identification, including a more quantitative account to how canonical word forms respond to different degrees of non-canonical acoustically varied input, but in our estimation the present model provides a well-founded framework that is consistent with the current body research on the effects of variability on both vocabulary learning and speech processing.

4. Summary and Conclusion

In this paper, we have presented a review of research on the effects of acoustic variability on (a) L1 speech processing, and in particular L1 word identification; and (b) vocabulary learning, mostly L2 vocabulary learning, but at least in one case, L1 vocabulary learning. The research in these two areas indicates that acoustic variability based on sources that are phonetically relevant, such as talker, speaking style, and speaking rate, negatively affect L1 speech processing but positively affect vocabulary learning (mostly L2 vocabulary learning to date, and at least in the case of talker variability, also L1 vocabulary learning). Acoustic variability based on sources that are not phonetically relevant to listeners, such as amplitude and fundamental frequency (at least for native English speakers), have produced no significant effects on L1 speech processing, however.

Interestingly, the same phonetically relevant types of acoustic variability (talker, speaking style, speaking rate) that produce negative effects on speech processing also produce positive effects on (mostly L2) vocabulary learning whereas acoustic variability based on other sources, such as amplitude and fundamental frequency (F0) (at least for native speakers of English), yield null effects, mirroring the pattern observed for speech processing precisely when it comes to effects versus null effects for all of the different types of acoustic variability observed to date. The predictions of Sommers and Barcroft's (2007) extended phonetic relevance hypothesis are consistent with this overall pattern of effects, as are the findings of Barcroft and Sommers (accepted pending revisions) demonstrating that speakers of a tone language experience improved L2 vocabulary learning with F0-varied speakers whereas non-tone language speakers do not.

We also have presented a connectionist-oriented (emergentist) model that depicts how phonetically relevant acoustic variability positively affects vocabulary learning, poses costs during speech processing, and continues to shape the canonical forms of lexical items in the mental lexicon across the lifespan. Clearly, new research is needed to expand upon the existing body of research on different sources of acoustic variability, vocabulary learning, and speech processing. Such research can continue to test the predictions of the extended phonetic relevance hypothesis by examining, for example, whether F0 variability negatively affects L1 word identification among speakers of a tone language such as Zapotec, as the hypothesis would predict. Other research can test predictions of the model presented in this paper, help to refine the model, or both. Research in this area should continue to improve our understanding of the fascinating patterns that have been observed to date regarding the relationship between acoustic variability, vocabulary learning, and speech processing.

References

Assmann, P., Nearey, T. M., & Hogan, J. (1982). Vowel identification: Orthographic, perceptual, and acoustic aspects. *Journal of the Acoustical Society of America*, 71, 975-989.

Barcroft, J., & Sommers, M. S. (2005). Effects of acoustic variability on second language vocabulary learning. *Studies in Second Language Acquisition*, 27, 387-414.

Bradlow, A. R., & Pisoni, D. B. (1999). Recognition of spoken words by native and non-native listeners: Talker-, listener-, and item-related factors. *Journal of the Acoustical Society of America*, 106, 2074-2085.

Bradlow, A.R, Nygaard, L.C. & Pisoni, D. B. (1999). Effects of talker, rate, and amplitude variation on recognition memory for spoken words. *Perception and Psychophysics*, 61, 206-219.

Church, B. A. & Schacter, D. L. (1994). Perceptual specificity of auditory priming: Implicit memory for voice intonation and fundamental frequency. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 20, 521-533.

Goldinger, S. D., Pisoni, D. B., & Logan, J. S. (1991). On the nature of talker variability effects on recall of spoken word lists. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, 17, 152-162.

Mullennix, J. W., Pisoni, D. B., & Martin, C. S. (1989). Some effects of talker variability on spoken word recognition. *Journal of the Acoustical Society of America*, 85, 365-378.

Nygaard, L. C., Sommers, M. S., & Pisoni, D. B. (1995). Effects of stimulus variability on perception and representation of spoken words in memory. *Perception & Psychophysics*, 57, 989-1001.

Palmeri, T. J., Goldinger, S. D., & Pisoni, D. B. (1993). Episodic encoding of voice attributes and recognition memory for spoken words. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, 19, 309-328.

Sommers, M. S., & Barcroft, J. (2005). Effects of variability in voice quality and fundamental frequency on spoken word identification. Manuscript submitted for publication.

Sommers, M., & Barcroft, J. (2007). An Integrated Account of the Effects of Acoustic Variability in first language and second language: Evidence from Amplitude, Fundamental Frequency, and Speaking Rate Variability. *Applied Psycholinguistics*, 28, 2, 231-249.

Sommers, M., & Barcroft, J. (2011). Indexical Information, Encoding Difficulty, and Second Language Vocabulary Learning. *Applied*

Psycholinguistics, 32, 2, 417-434.

Sommers, M.S., Nygaard, L. C, & Pisoni, D. B. (1994) Stimulus variability and spoken word recognition. Effects of variability in speaking rate and overall amplitude. *Journal of the Acoustical Society of America*, 96, 1314-1324.

Takayanagi, S., Dirks, D. D. & Moshfegh, A. (2002). Lexical and talker effects on word recognition among native and non-native listeners with normal and impaired hearing. *Journal of Speech, Language and Hearing Research*, 45, 585-597.