

Bilingual Speech and Exemplar Theory

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11.1 Introduction

The “speech chain” invites the image of a talker on one end and a listener on the other. In producing speech, the talker, while limited anatomically and physiologically in what they can utter, has some amount of agency as they sample from their production repertoire (e.g., styling one’s speech appropriately for an infant or an adult). The selected linguistic message exits the vocal tract via a motor plan that orchestrates a number of articulatory actions, and results in an audiovisual speech signal that is complex and noisy. The listener engages in a multifaceted mapping process that requires them to identify, synthesize, and prioritize a multitude of acoustic and visual cues from the incoming signals in real time. The information received by the listener is rich and allows for the processing of the linguistic message (e.g., an offer of coffee), the talker’s identity (e.g., from your friend Sahil), in addition to larger pragmatic and contextual cues (e.g., in a noisy coffee shop where other voices, perhaps in other languages, compete for your auditory attention). This talker-and-listener dynamic takes place between individuals, but also *within* an individual in a posited production-perception link. A strong connection between an individual’s production repertoire and their perceptual representations is at the heart of exemplar-based theories of speech: simply, a listener’s auditory experiences feed into the available forms for production.

Before laying out the assumptions within any exemplar-based model, an initial foray into complicating the outlined phonetic space for bilinguals is necessary. We attempt to do so initially without introducing the theoretical assumptions and jargon of any particular framework. Starting with the more observable speech production, a bilingual’s two languages often, but not always, exhibit cross-language mutual influence (see Section 11.3.2). For example, the Cantonese /u/ from a Cantonese-English bilingual may be a little English-like and the English /u/ may be a little Cantonese-like. This observation suggests that *somewhere* within the production pipeline there is

a link between Cantonese and English. In perception, there is also evidence of mutual influence (see Section 11.3.1), but the situation for a bilingual listener can be a bit more complicated. For example, a bilingual listener needs to be able to adjust their thresholds and categories for phonetic and phonological units based on the language. This adjustment requires that listeners use signal-based information (or other environmental cues) to identify the language and adapt accordingly. Evidence from early bilinguals and proficient second language learners shows that certain bilinguals can, indeed, adjust their categorization boundaries in this way (Casillas & Simonet, 2018).

11.2 The Basics of Exemplar-Based Theories

A shared proposition of any exemplar model is that phonetic detail beyond the abstract phonological category, often accompanied by social and speaker-specific information, is part of linguistic knowledge (Goldinger, 1996, 1998; Johnson, 1997; Pierrehumbert, 2002, 2003; Sumner et al., 2014). The evidence is unclear whether the social information is part and parcel of the linguistic representation or connected via an associative network. A note on terminology is crucial here, as what *exactly* is represented in an “episode” or any linguistic representation is the million-dollar question. Exemplar-based models are often caricatured with claims that speakers/listeners have spectrograms (or cochleagrams or some other auditorily informed transformation of the acoustic signal) dancing around in their heads. This caricature is often used to deride exemplar-based models, but rightfully points to the elephant in the room: the exact nature(s) of the mental representation of speech is unknown. While we do not yet know the exact nature of sound-based linguistic representations in the mind, behavioral work has shown us that users of language are keenly aware of phonetic information and its associated linguistic and social meaning on implicit and, occasionally, explicit levels. These behavioral results are supported by a growing body of work in neurolinguistics. The superior temporal gyrus decodes phonetic detail (Mesgarani et al., 2014) and the auditory cortex facilitates talker-specific cues in the context of vowel normalization (Sjerps et al., 2019), implicating the regions of the brain involved in the processing of phonetic detail. In short, while exemplar models often use variable terms such as *sub-phonemic*, *episodic-acoustic*, *indexical*, *fine-grained representations*, and so on, what these terms have in common is an acknowledgment that phonetic and phonological knowledge exists below the phonemic or allophonic levels. The goal of the current chapter is not to adjudicate between such labels. We globally refer to this body of literature as exemplar models to be contrasted with purely abstract models (see Section 11.4.1).

While early work paved the way for existing exemplar interpretations and models in the field of linguistics (e.g., Goldinger, 1996; Hintzman, 1986; Johnson, 1997; Nosofsky, 1986, 1992; Pierrehumbert, 2002, 2003), the core tenets of exemplar-based theories have a long history in cognitive psychology.

Much of the seminal behavioral evidence that talker-specific phonetic detail facilitates the processing of spoken language came from word and talker recall tasks: listeners are more accurate at recalling words as previously heard when presented with a word in the same voice (e.g., Palmeri, Goldinger, & Pisoni, 1993). Word identification and categorization paradigms have also been used to demonstrate listeners' sophisticated knowledge of which social groups produce which sounds in which ways (e.g., Hay, Warren, & Drager, 2006).

The assumption that listeners have detailed phonetic knowledge that can be yoked to social and contextual categories is relatively widespread across many areas of linguistics, beyond phonetics and phonology – for example historical linguistics and language change (Skousen, 1989; Todd, Pierrehumbert, & Hay, 2019; Wedel & Fatkullin, 2017) and child phonological acquisition (Jusczyk, 1993). Crucially, however, any viable theory or model that includes exemplar-like representations must also include mechanisms for abstraction at various levels in the linguistic system. The need for abstraction to operate over experiences has been noted by prominent theorists (Pierrehumbert, 2016).

We continue with two assumptions about exemplar-based models. The first assumption is that any flavor of an exemplar model provides users with sensitivity to phonetic detail. This sensitivity does not mean that all phonetic detail is encoded or weighted equally in a linguistic representation. What listeners attend to and encode in the phonetic detail is also not fixed, but can evolve over time. This is, arguably, particularly important in the bilingual context as individuals' exposure to and experience with languages change over the life span. The second assumption is that phonetic knowledge – at a detailed or abstracted level – is associated with social and contextual information, connecting “core” linguistic knowledge with indexical and sociopragmatic cues and categories. This disperse network contextualizes speech and language in the socially rich world that individuals inhabit.

11.3 Shared Linguistic Structures

Before we examine how an exemplar model can accommodate bilingual information, we must consider the linguistic structures that have been posited to be connected across an individual's language systems. This is not a chapter on the robust evidence for cross-linguistic connections, but we must visit this topic to make apparent the required cross-linguistic links within a bilingual exemplar model. In our too-brief overview here, we focus on the sound-based level, extending to lexical and social categories. The body of work on bilingual cross-linguistic influence is expansive, and growing at an impressive rate. Our discussion here touches on only a fraction of the important work that has been conducted in this area, and should not be considered an exhaustive summary by any means.

11.3.1 Perception

Cross-linguistic connections in perceptual representations have a long-studied history,¹ approached heavily from the perspective of second language acquisition. Two popular frameworks within the language learning space are the Perceptual Assimilation Model-L2 (PAM-L2; Best & Tyler, 2007) and the Speech Learning Model (SLM; Flege, 1995). These frameworks postulate connections between perceptual categories across languages such that category boundaries are nudged on account of cross-linguistic mutual influence. The revised SLM framework, the SLM-r (Flege & Bohn, 2021), is an updated and more dynamic model that allows for continual reorganization of cross-linguistic connections across the life span (Flege & Bohn, 2021). We recommend Chang (2019) as an overview on the phonetics of second language learning.

While early work indicated that bilinguals may exhibit perceptual behaviors that are between those of monolingual groups from the respective languages (Caramazza et al., 1973), subsequent work focusing on early bilinguals and highly proficient late bilinguals suggests that these groups perceptually shift their categorization boundaries based on the language they are perceiving. For instance, the threshold for stop voicing in different languages (e.g., /b/ vs. /p/) is shifted along a voice onset time (VOT) continuum for Spanish-English bilinguals, suggesting that listeners can rely on different, and thus separable, categories in perception and recognition.² This behavior is called a double phonemic boundary (Casillas & Simonet, 2018; Garcia-Sierra, Diehl, & Champlin, 2009; García-Sierra et al., 2012; Gonzales & Lotto, 2013). Bilinguals may also switch in and out of language modes based on previously heard speech, social and pragmatic environments, or linguistic cues. Those linguistic cues may be phonotactic or subphonemic in nature. Not all perception tasks point to the same linguistic knowledge. For example, Antoniou, Tyler, and Best (2012) examined early bilinguals' performance on categorization, goodness ratings, and discrimination tasks. Language-specific patterns were found for categorization and goodness rating responses, but not discrimination, which appeared to be dictated by the more dominant language of the listener. While more work is necessary to fully understand the effects of perceptual modes on listening for bilinguals, it is clear that bilinguals, particularly early bilinguals, exhibit sensitivity to phonetic details.

11.3.2 Production

Across a range of methods, there is clear and robust evidence that bilingual speech production can show cross-linguistic influence (e.g., Baker &

¹ We use the term "perceptual representations" here as a generic term for any phonetic or phonological representation that is used in the process of apprehending and comprehending speech.

² Our inclusion of the terms "perception" and "recognition" points to the occasional need to distinguish lower-level perceptual processes and what was actually heard from higher-level decision-making processes, where an individual categorizes or reports on a sound or word. See this terminology in use in Samuel (2020) and Zheng and Samuel (2017).

Trofimovich, 2005; Barlow, 2014; Flege, 1987; Fricke, Kroll, & Dussias, 2016; Major, 1992; Olson, 2016; Sancier & Fowler, 1997; Simonet, 2011). This cross-linguistic influence suggests the existence of linked categories. However, early bilinguals can maintain distinct phonetic categories across their two languages (e.g., Guion, 2003; Sundara, Polka, & Baum, 2006; MacLeod, Stoel-Gammon, & Wassink, 2009) and the evidence that bilinguals habitually produce compromised categories – those that average across the categories of their multiple codes – is not particularly strong (Casillas, 2021). Multilingual individuals are socially sophisticated, capable of performing different degrees of cross-linguistic influence in pronunciation variation based on social demands (Bullock & Toribio, 2009). As such, a model of bilingual speech production must allow for the interaction of phonological and phonetic categories without the requirement that one language's categories subsume the other's. The degree of cross-linguistic influence also needs to be flexible synchronically and across an individual's life span (Simonet & Amengual, 2020). The dynamic nature of the strength of cross-linguistic influence in production is apparent in studies that manipulate language mode (Grosjean, 1998, 2008). In experimental contexts where researchers attempt to present a unilingual mode, bilinguals can show, for example, phonetic patterns that are equivalent to monolingual norms (e.g., Antoniou et al., 2010; Henriksen et al., 2021), whereas conditions that prompt a multilingual mode through, for example, code-switching elicit cross-linguistic influence in phonetic patterns (e.g., Henriksen et al., 2021). The empirical evidence is mixed for whether language mode effects vary as a function of language dominance (e.g., Amengual, 2018; Simonet, 2014).

11.3.3 Social Meaning

The subphonemic variation in speech that is associated with social identity is rich, and well-studied within monolingual populations. There appears, however, to be limited research in this domain in bilingual populations. One notable study was Szakay, Babel, and King (2016), who queried the social associations across languages and dialects in the New Zealand context with a sample of English-Māori bilinguals. New Zealand English has two main varieties: Māori English and Pakeha English. These Englishes are associated with ethnically Māori and ethnically (white) European individuals, respectively. Māori English is acquired as a native variety of English and is positively associated with Māori culture and identity in New Zealand (Holmes, 2005; Maclagan, King, & Gillon, 2008). Szakay et al. (2016) assessed whether the Māori social association with Māori English led to stronger L2 (Māori)-L1 (English) priming when Māori English was the target, as opposed to Pakeha English. We walk through this hypothesized social connection with the lemma *snow*. (See figure 1 in Szakay et al. [2016] for a schematization to accompany our description.) This lemma concept of “white flakes of frozen water vapor” exists in both languages and has distinct lexemes in each language, which can be orthographically represented as *huka* and *snow*. Stronger connections at the

lemma level exist in the mapping of the L1 lexeme to the L2 lexeme through the lemma, often seen as the stronger effect of L1–L2 priming (e.g., Jiang & Forster, 2001) compared to the weaker links in the L2–L1 direction. Of note in our example with *snow*, the GOOSE vowel in New Zealand English exhibits pronunciation variation indexed to Māori and Pakeha identities, with realizations of *snow* as [snøʊ] and [snɐʊ], respectively, in Māori English and Pakeha English.³ The social link between the Māori English pronunciation of *snow* [snøʊ] and the Māori HUKA [hʊkʌ] was hypothesized by Szakay et al. (2016) to facilitate L2–L1 priming for Māori English targets. Indeed, they found that Māori effectively primed Māori English, but not Pakeha English, suggesting that a social category connection facilitated L2–L1 processing. Listeners were sensitive to the subphonemic variation in the Māori English that indexed Māori identity, which is also intricately connected to the Māori language itself.

This particular example of cross-linguistic dialect-specific L2–L1 priming is crucial because the lack of shared phonemes in Māori HUKA and English *snow* strongly suggests that the cross-language activation *must* come from subphonemic cues. Indeed, Māori English and Māori are known to share suprasegmental similarities (Szakay, 2012). Listeners must be sensitive to these subphonemic suprasegmental differences in order to utilize them in the creation, maintenance, and use of a social Māori category across codes. This is a classic example of the fine-grained phonetic detail in an exemplar network being used to facilitate linguistic processing.

11.4 Building Toward a Framework

The overview of shared linguistic structures in bilinguals identifies the desiderata for a bilingual exemplar model. In perception, listeners are able to operate in distinct language modes as a function of language experiences (e.g., age of acquisition, continued language use, etc.). In production, coactivation of an individual's languages entails the possibility for cross-linguistic (mutual) influence. This influence may be observed on cross-linguistically linked phones or at the lemma level, which connects concepts and translation equivalents. Social information carried in the speech stream may also link distinct languages.

11.4.1 Phonetic Details and Abstract Categories

Exemplar models have historically been contrasted with abstract models, where mental representations of language are exclusively available in an abstracted form, leaving fine phonetic detail unrepresented (e.g., Cohort: Marslen-Wilson, 1984, 1987; TRACE: McClelland & Elman, 1986; Shortlist: Norris, 1994). In

³ Small cap *goose* follows the lexical set notation devised by Wells (1982). It is used to denote the set of lexical items that contains the vowel in the word *goose*.

these types of models, while token-specific information may be perceived in the speech signal, a normalization process results in a more abstract sublexical representation, with models differing in the nature of the abstract sublexical units (Weber & Scharenborg, 2012). The dichotomy between abstract and exemplar interpretations was more explicit in early phonetic research. For instance, in a study by Pallier, Colomé, and Sebastián-Gallés (2001), Catalan-Spanish bilinguals, varying in Spanish or Catalan dominance, were tested in a “medium-distance” primed auditory lexical decision task. Minimal pairs bearing Catalan-specific vowel contrasts were separated across eight to twenty trials (e.g., /netə/ “granddaughter” – /netə/ “clean, *fem.*”) and matched with corresponding identity pairs (e.g., /netə/ – /netə/; the same word is repeated twice, but as acoustically unique instances). Pallier et al. (2001) observed that Catalan-dominant speakers showed priming for identity pairs and not minimal pairs, while Spanish-dominant speakers showed priming for *both* identity pairs and minimal pairs. These findings were taken as evidence in support of abstract models and not exemplar models, since Spanish-dominant speakers could only have demonstrated minimal pair priming if the Catalan contrasts were being assimilated to native language categories, with minimal pairs in Catalan being perceived as identity pairs.

Recent work has provided growing empirical evidence in support of hybrid models that assume that linguistic knowledge is composed of both abstract and exemplar representations: listeners are sensitive to phonetic detail and make generalizations over and across both experienced items and abstract categories (Pierrehumbert, 2016). Lexically guided perceptual learning paradigms offer a nice example of the need for both attention and retention of phonetic detail and generalization over categories. In these paradigms, listeners are exposed to novel pronunciations in the context of a lexical frame. This lexical frame provides the scaffolding necessary for a listener to connect the novel pronunciation to a particular phoneme or allophone. This exposure causes an adjustment of a category, such that listeners’ categories accommodate the new pronunciation variation. The empirical support for perceptual adaptation is robust (e.g., Eisner & McQueen, 2006; Jesse, 2021; Kraljic & Samuel, 2007; McQueen, Cutler, & Norris, 2006; Norris, McQueen, & Cutler, 2003; Samuel, 2016), and the literature includes work on bilinguals (Bruggeman & Cutler, 2020; Chan, Johnson, & Babel, 2020; Cutler, Burchfield, & Antoniou, 2019; Drozdova, Van Hout, & Scharenborg, 2016; Reinisch, Weber, & Mitterer, 2013). Within bilingual populations, however, the results are somewhat mixed. While there is evidence that bilinguals show adaptation in their second language (Drozdova et al., 2016; Reinisch et al., 2013), some data suggest that a bilingual’s less-dominant language may not be so adaptable (Bruggeman & Cutler, 2020; Cutler et al., 2019; but see also Chan et al., 2020). What is important for the current purposes here is that a prerequisite for adaptation is sensitivity to phonetic details that connects with phonological categories. It may be that, in some bilingual scenarios, the appropriate

connection strength may be lacking. This sets the stage for the crucial next step of this chapter: the introduction of a particular exemplar model.

11.4.2 Weaving Bilingualism into an Exemplar Model

It is apparent that a model of speech perception needs to provide the structure and the mechanisms to account for sensitivity to phonetic detail and the ability to abstract and generalize. Exemplar-based models typically abstract generalizations of experienced items. One must remember, however, that this does not mean that all experienced items are treated equivalently. Variation is socially weighted such that not all experienced items may contribute equivalently to the category (Sumner et al., 2014). In many exemplar models, a production–perception feedback loop is central to the model’s architecture (e.g., Ettlinger, 2007; Harrington et al., 2018; Pierrehumbert, 2002; Sóskuthy, 2015; Todd et al., 2019; Tupper, 2015; Wedel & Fatkullin, 2017). Note that none of these frameworks are designed to model bilingual knowledge, but at the heart of many is the tagging of phonetic variation with respect to its social and pragmatic contexts. While it is not a stretch to adapt such a concept to the tagging of *language*, what becomes complex and messy is the nature of the connections across languages within a bilingual.

Let us walk through the basic structure of Todd et al. (2019), a recent instantiation of an exemplar-based model, and note opportunities for bilingualism to factor into the model. We focus on the model by Todd et al. (2019) because it is computationally implemented (on a small scale) and thus well-specified, and it builds upon the seminal work by Pierrehumbert (2001), which is, arguably, the most well-known exemplar model in linguistics. This multi-layered framework builds on crucial insights from previous exemplar models (e.g., Harrington et al., 2018; Johnson, 1997; Nosofsky, 1986; Sóskuthy, 2015; Wedel, 2006, 2012; Wedel & Fatkullin, 2017), but is unique in its integration of these stages into a single architecture. Todd et al. (2019) advance an exemplar-based computational model where the role of the listener is emphasized in navigating and organizing phonetic variation. While this description sounds as though it affords the listener some amount of agency in the process, the point is that the processes of perceiving, categorizing, encoding, and recognizing are iterative, and transform the original signal into a mental representation that has been evaluated several times over. This provides multiple opportunities for bilinguals’ multifaceted linguistic knowledge to be integrated into an exemplar framework.

Let us begin with establishing that, in this model, *CATEGORIES* and *TYPES* are abstract generalizations of experienced phonemes and words, respectively. In terms of the architecture, we start on the listener side of the production–perception loop. In Todd et al. (2019), *ACTIVATION* is the first stage in perception, where an item activates other similar exemplars within a distributional space. Note that the nature of the phonetic detail involved in

this activation and similarity-matching process is unspecified.⁴ The apprehension of an utterance results in *ACTIVATION*, a process that excites other exemplars based on their distance in perceptual-acoustic space. What aspects of the signal are grounds for a similarity assessment in activation is an opportunity for bilingual interaction. A bilingual will have not only different but more categories and types available for activation than a monolingual. The similarity assessment can also change in the context of language learning. For example, as native speakers of Korean learn English, they adjust their spectral and duration cue weights for the /i/–/ɪ/ contrast in English (Kim, Clayards, & Goad, 2018). In learning to weigh the spectral cue more heavily, individuals may use the spectral information more prominently in the similarity assessment in the activation phase.

After activation comes *IDENTIFICATION*, which is the process of recognizing the category, as informed by the phonological frame or word in which it is contextualized. The process of identification does not equal encoding, however, as encoding is achieved only if the item passes the *DISCRIMINABILITY* and *TYPICALITY* evaluations. Discrimination is a comparison of the ratio of category activations to the discriminability threshold. The equation implemented by Todd et al. (2019) has an equivalent approach in Nosofsky (1986). This part of the process is yet another opportunity where the bilingual experience is relevant. If a bilingual's categorization threshold is lower, this will lead to an increase in discriminability, regardless of the activation threshold achieved. We assume that lexical biases are built upon robust abstractions at the phonological level. Second language learners exhibit less lexical bias (Samuel & Frost, 2015; Soo et al., 2020), which may be a reflection of decreased thresholds for some types of bilinguals. Typicality is a comparison of the activation of the intended category to the typicality threshold. When activation is higher than the threshold, this increases the likelihood of that particular token passing the typicality evaluation. In Todd et al.'s (2019) model, both discriminability and typicality are probabilistic in nature. If a token is not well discriminated or is deemed atypical, it does not pass the thresholds in the discrimination and typicality evaluation stages. Correspondingly, it will not be stored and will, therefore, not be allowed to update the system. Here, an important question to consider in the context of bilingual listeners is what speech patterns are part of the typicality assessment. In many parts of the world, diaspora communities foster heterogeneous bilingual populations with exposure to a range of pronunciation variants. In Canada, for instance, the cultural mosaic means that Cantonese-English bilinguals are exposed to Cantonese, English, Cantonese-accented English, and English-accented Cantonese since birth. Which varieties benefit from their own category aggregates? Which compete or coalesce into

⁴ The model described in Todd et al. (2019) is a computational model that has formant values as input. Certainly, more sociolinguistic and subphonemic detail could and should be considered as part of the exemplar representation, but, as we note in the text, the exact nature of representations is a large and looming question in this literature.

a more or less cohesive system? Crucial questions like these need to be addressed in order to properly extend an exemplar model to bilingual listeners.

For bilinguals who speak related languages, these steps of identification, discrimination, and typicality evaluation are ideal opportunities for language interaction, as cognates can lead to cross-linguistic activation that blurs phonemic contrasts. Let us consider, for example, Amengual (2016a), who examined Majorcan Catalan-Spanish bilinguals' production and lexical processing of the /ɔ/-/o/ contrast in Catalan. Crucially, this contrast does not exist in Spanish. Participants – whether Catalan or Spanish dominant – produced less of a difference between Catalan /ɔ/ and /o/ in words that were cognates compared to noncognate items, suggesting phonetic interference in production. In terms of lexical processing, the results of a lexical decision task suggest coactivation of Spanish and Catalan lexicons. For congruent cognates, this had the effect of increasing listeners' abilities to correctly identify words and non-words, but the coactivation increased error rates for incongruent cognates.⁵ Amengual (2016a) identifies exemplar models as a framework that accounts for the necessary link between lexical and subphonemic structures within and across languages. To accommodate these findings, the similarity of the phonological frames in the cognate items must form part of the assessment of like sounds in the target window for typicality evaluation.⁶ For cognate items, this coactivation would include both Catalan /ɔ/ and Spanish /o/, ultimately inviting the conflation at the lexical level, which manifests as increased acceptability of “incorrect” pronunciations in Catalan words. Ultimately, this coactivation would cause cross-linguistic influence on lexical items independent of the cognate status (Amengual, 2016b).

A token is stored or encoded if it passes both the discriminability and the typicality evaluations. In Todd et al.'s (2019) model, the storage process overwrites a randomly selected exemplar within the same space. If bilinguals experience more variability in their environment, potentially by virtue of experiencing their languages spoken by individuals who vary in terms of their proficiency and accentedness, they could have consistently lower thresholds than monolingual individuals, leading to an exemplar space that has wider distributions.

We turn next to speech production, which first involves sampling from the pool of stored exemplars. The first pass is called *TYPE SELECTION*, which is the selection of the lexical item. *TARGET SELECTION* is the selection of an exemplar that provides an acoustic target. The sampling from the type and token space can pull a lexical item or pronunciation variant that has more or fewer sociocultural associations with one language or another, potentially affecting a bilingual's target pronunciation. The language-specificity of the target selection may be influenced by language mode or the magnitude of language

⁵ Examples of the stimuli types are as follows: congruent cognates for *mouth*: Catalan /boka/ and Spanish /boka/; incongruent cognates for *sun*: Catalan /sol/ and Spanish /sol/; noncognates for *oil*: Catalan /oli/ and Spanish /aθeite/.

⁶ This possible mechanism is described in the supplementary materials of Todd et al. (2019).

activation, where acoustic targets may be sampled from a single language distribution or a distribution composed of both languages or a single language distribution that is pulled by the competing language (Amengual, 2018; Brown & Copple, 2018; Johnson & Babel, 2023; Simonet & Amengual, 2020).

The last two stages in production can nudge a pronunciation in different directions. First, a *BIAS* parameter conditions category behavior – in Todd et al.'s (2019) model this is a crucial aspect for modeling the dynamics of sound change, which we can broadly envision as a balance of stability (e.g., maintain categories) and change (e.g., a pull in a particular direction or dimension). In sound change, typically, socially structured variation within the community gets pushed or pulled in various ways, the direction of which may relate to the exact nature of the phonetic variation (Harrington & Schiel, 2017; Harrington et al., 2018). Such a dynamic is not unlike the cross-linguistic influence in bilinguals (for a recent attempt to connect the sound change and cross-linguistic influence literatures, see Johnson and Babel, 2023). We see the bias stage as a prime opportunity for mutual influence in bilinguals. The final stage before an item is unleashed in the acoustic space is *IMPRECISION*, which is random noise added to the target form. For bilinguals, we can imagine that an aspect of imprecision is an opportunity for the global activation of the non-target language to bias and shift pronunciation. Language-specific articulatory settings and interspeech postures may manifest as cross-linguistic influence at either the bias or the imprecision stage (Mennen et al., 2010; Wilson & Gick, 2014;). This could provide an explanatory mechanism for phonetic drift in L1–L2 language dynamics (Chang, 2012; Guion, 2003).

11.5 It's Complicated

In this final section, we briefly discuss challenges in the study of bilingualism that are a bit thorny for exemplar-based models: cross-linguistic similarity and the heterogeneity within and across bilinguals. We close with a discussion and recommendations for ongoing efforts at quantifying bilingualism in the context of exemplar models.

11.5.1 Similarity

The degree of cross-linguistic similarity is an important factor in exemplar-based models, as the similarity of languages and linguistic structures influences the kinds of connections that can be made within a bilingual (e.g., Yao & Chang, 2016). Similarity is relevant at multiple dimensions within an exemplar model: phonetic forms, phonemic forms, and lexical similarity. A level of linguistic analysis on the part of the speaker-listener is relevant, as sound-based similarity relationships may be better accounted for at a certain level of abstraction, as opposed to phonetic similarity (Chang et al., 2011; Flege, 1987); see Chang (2019) for an overview.

The similarity between languages is continuous and multidimensional. Importantly, similarity along one dimension (e.g., phonemic categories) does not entail similarity along another dimension (e.g., existence of cognates). The scaling up of exemplar-based theories to account for bilingualism should also offer accounts and make predictions about bidialectalism, where cross-code similarity is presumably greater than cross-linguistic similarity. The question of how processes related to bidialectalism compare to those involving bilingualism is poorly understood as comparison between bilingual and bidialectal population groups has historically been avoided (Chevrot & Ghimenton, 2018). We suggest, however, that the omission of bidialectalism from theoretical discussions about similarity, cross-language competition, and exemplar models is a missed opportunity to better understand the similarity quantification(s) that individuals engage in.

11.5.2 Heterogeneity within and across Bilinguals

The challenge in an exemplar-based model for bilingualism is not simply the increased complexity from the addition of another language. There is also the fact that bilinguals may be vastly different from one another.

A large body of work both within and across languages and dialects has made clear that bilinguals are not all the same. Nor should a bilingual be considered two monolinguals – complete or incomplete – in one (Grosjean, 1998). Bilinguals' phonetic behaviors are informed by a number of (interacting) language factors, such as age and order of acquisition (e.g., Canseco-Gonzalez et al., 2010; Montrul & Foote, 2014), age of arrival (e.g., Flege, Munro, & MacKay, 1995; Flege, Yeni-Komshian, & Liu, 1999), length of residence (e.g., Flege & Liu, 2001), sociocultural identity (e.g., Szakay et al., 2016), language usage patterns (e.g., Bruggeman & Cutler, 2020; Chan et al., 2020), and language dominance (e.g., Casillas & Simonet, 2016; Soo & Monahan, 2023), to name but a few. Altogether, the myriad factors that contribute to bilingual behavior and linguistic organization suggest that bilingualism is best conceptualized as a continuum.

That bilingual individuals vary is, of course, no surprise to any bilingual researcher. Heterogeneity even within controlled populations is the norm. Yet, in the context of exemplar-based models, this variation is particularly important. The factors described just now set the stage for the organization of the bilingual's linguistic system and its evolution over time. The similarity assessments within a bilingual exemplar model and the cross-linguistic activation that colors mutual influence will be conditioned by the nature of the bilingualism, which for any individual will likely shift over time.

11.6 Where Do We Go from Here?

Independent of the heterogeneous nature of bilingual individuals and speech communities is the challenge of how to quantify any sort of

bilingualism in the first place. There has been no lack of trying. In her dissertation, Bruggeman (2016) provides an amusing litany of definitions and means of quantifying language dominance that have been advanced (tables 2-1 and 2-2 in Bruggeman, 2016). These measures have historically fallen short, as bilingualism is complex, multifaceted, and dynamic at both small scales (e.g., a heritage speaker's familiarity with kinship and domestic terms in the heritage language versus their broader use of the second language in institutional spheres) and large scales (e.g., immigrating to a country with different national languages). More recent metrics like the Bilingual Language Profile (Gertken, Amengual, & Birdsong, 2014) and language entropy (Gullifer & Titone, 2020) consider the multidimensional nature of language dominance, but both still attempt a quantification of something that may ultimately be unquantifiable (Marian & Hayakawa, 2021). We are not saying that measures of bilingualism do not have some utility – they very much do – but they need to be used with recognition of their limits.

These concerns exist in any bilingual research, but in the nebulous associative networks that connect social context to phonetic detail to lexicons, the challenge is more apparent. Bilingual individuals are complex. Language use varies across cultures, communities, and individuals, setting up a seemingly infinite array of social connections. How can we wrangle such a complex and variable topic? We, of course, do not have the ultimate answer, but we underscore the need for within-subject analyses, open science approaches, and transparency in hypothesis testing versus exploratory analyses. Altogether, this will allow the field to incrementally move toward a more complete understanding of the connections that bilinguals make within and across their languages between abstract representations, social context, and phonetic detail. In the context of exemplar models where sociocultural connections and metrics of phonetic and phonological similarity link linguistic forms, the heterogeneity of bilinguals makes specific predictions about speech and language particularly tricky. However, it is by welcoming the heterogeneity that we may ultimately reach an improved understanding of the representation of phonetic detail in bilinguals.

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