PAM-L2 and Phonological Category Acquisition in the Foreign Language Classroom

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Abstract

Models of second language (L2) speech learning are designed to account for phonological acquisition in the L2. Both the Perceptual Assimilation Model of L2 speech learning (PAM-L2; Best & Tyler, 2007) and the Speech Learning Model (SLM; Flege, 1995, 2003) have based their predictions on L2 acquisition by immersion in a predominantly L2 environment. However, many second languages are learned via formal instruction in a foreign language (FL) classroom, often in the learner's native language environment. Piske (2007) outlined how the principles of SLM might apply to the FL classroom, concluding that formal instruction should begin at an early age, there should be intensive foreign language use over an extended period of time, learners should have exposure to high quality input, and there should be training focused specifically on perception and production. The aim of this paper is to explore how the principles of PAM-L2 might complement those suggestions. The paper provides a thorough overview of PAM-L2, before outlining key characteristics of FL learning in the classroom that are likely to impact on L2 category acquisition, either positively or negatively. It also discusses methodological factors to be taken into consideration for any study investigating L2 category acquisition from a PAM-L2 perspective. Applying PAM-L2 to the FL classroom, the paper concludes that FL students need learning experiences that provide opportunities for them to discover the phonetic differences that signal phonological contrast in the L2. These experiences need to be provided at the earliest possible stages of learning, prior to the establishment of a large L2 vocabulary. A range of suggestions is provided for how PAM-L2 principles might be incorporated into FL learning curricula to maximise the opportunity for acquiring sensitivity to L2 phonological distinctions.

1. Introduction

The outcome of second-language (L2) acquisition in childhood is markedly different from adult L2 acquisition, particularly in the domains of phonetics and phonology. Older learners are much more likely than younger learners to speak with a detectable foreign accent. Less obvious to casual observation is the fact that late L2 learners are also likely to *hear* with an accent (Jenkins, Strange, & Polka, 1995). While some have attempted to explain these differences between early and late L2 acquisition as biological in nature, the most plausible explanation seems to be that the effects are due to the fact that the learner already has a first language (L1). Indeed, results from studies on cross-language speech perception, where listeners are presented with stimuli from a never-before-heard non-native language, consistently show a profound influence of the L1 on the perception of non-native phones. It comes as no surprise, then, that the L2 learner's perception and production is heavily influenced by prior learning of the L1.

The two most influential models of how the L1 influences L2 speech learning are the *Speech Learning Model* (SLM; Flege, 1995, 2003) and the *Perceptual Assimilation Model of Second Language Speech Learning* (PAM-L2; Best & Tyler, 2007). SLM was designed to provide a framework for predicting the likelihood of acquiring new phonetic categories in the L2, and it applies to both L2 production and perception. PAM-L2, on the other hand, is concerned with perception only. Both models assume a learner with no prior knowledge of the L2, who is acquiring the L2 by immersion in an L2-dominant environment. However, many people successfully acquire communicative competencies in a formal instruction setting in a predominantly L1 environment. Finding optimal conditions for L2 category acquisition is important for designing foreign-language (FL) curricula, but neither model was designed with a formal instruction setting in mind. Here, the term L2 acquisition is reserved for L2 learning in an immersion setting, and *foreign language acquisition* (FLA) is used for a classroom setting. Both models can be applied to FLA, in principle, but it may be more difficult to make clear predictions about category acquisition because students come to the learning situation with a varying degree of prior experience with L2 and classrooms differ in the degree of native-speaker input received by students. Nevertheless, with carefully designed and well-controlled studies it may be possible to test general predictions in a classroom FL context. Piske (2007) has already outlined how the principles of SLM might apply to classroom FLA. He concluded

that FLA should begin in school at a young age, provided that there is high-quality L2 input, opportunities for intensive language use over a period of years, and that curricula should include specific training in perception and production of L2 phonemes. This chapter will focus on how the principles of PAM-L2 might complement the suggestions already made on the basis of SLM. For a general comparison of PAM-L2 and SLM, see Best and Tyler (2007). Specifically, the aims of this chapter are to:

1) Outline how the theoretical principles underlying PAM-L2 might apply to classroom FLA;
2) Identify methodological requirements for investigating L2 category acquisition in a classroom context, and;
3) Suggest possible avenues for incorporating PAM-L2 principles into FL learning curricula.

2. The Perceptual Assimilation Model of Second Language Speech Learning (PAM-L2)

To be able to explain how PAM-L2 might be applied to FLA, first it is necessary to summarize the model. As it has been over 10 years since the publication of Best and Tyler (2007), this also provides an opportunity to elaborate on the principles of the model using more recent experimental findings.

PAM-L2 is based on the Perceptual Assimilation Model (PAM; Best, 1993, 1994, 1995). PAM was designed to account for how the native language shapes perception of consonants and vowels. Research on infant speech perception informs PAM on how a native phonology develops (e.g., Best & McRoberts, 2003; Best, McRoberts, LaFleur, & Silver-Isenstadt, 1995; Tyler, Best, Goldstein, & Antoniou, 2014), and research on adult cross-language speech perception provides evidence for how prior learning of the native language influences perception (e.g., Best, McRoberts, & Goodell, 2001; So & Best, 2014; Tyler, Best, Faber, & Levitt, 2014). To test this influence, adults who are functional monolinguals are presented with contrasting phones from a never-before-heard non-native language. The participants of cross-language speech perception studies are not actively trying to learn to communicate in that language. Rather, the non-native language is used as a tool to probe the influence of native-language tuning on speech perception. PAM-L2 takes the functional monolingual as its starting point and assumes a learner who is actively acquiring an L2 in an environment where the L2 is predominantly spoken (i.e., via immersion). PAM-L2 assumes that the perceptual system is shared by all

of the learner's languages. If certain L1 phonological categories function adequately for discriminating L2 contrasts, then no additional learning is required for those contrasts. On the other hand, if the learner does not detect an L1 contrast for a given pair of L2 phonemes, then perceptual learning is required to be able to detect the L2 phonological contrast, and to build an L2 vocabulary that preserves a phonological distinction between those phonemes. How successful the learner is at detecting new phonological contrasts in the L2 is dependent on how the L2 phonemes are initially assimilated to the L1 phonological system.

PAM considers perceptual assimilation to the native phonology in two ways. First, an individual non-native phone can be categorized as a good, acceptable, or poor instance of a native category, uncategorized (i.e., it is not perceived as an instance of any one native category), or non-assimilable (i.e., it is not perceived as speech). As explained by Best (1994, pp. 261-262), the information that defines phonological category membership is only one small part of the L1 phonology, and it may differ qualitatively from the information that defines the systematic relationships *between* categories in a phonological system. Thus, PAM also considers perceptual assimilation of pairs of contrasting non-native phones and makes predictions about discrimination on the basis of the contrast assimilation type. If the non-native phones are each assimilated to a different L1 phonological category then this is termed a two-category assimilation. Discrimination is expected to be excellent because, serendipitously, the perceiver is able to detect an L1 phonological contrast between the non-native phones. When both non-native phones are assimilated to the same native category, there is no L1 phonological contrast to support discrimination, but the perceiver may be sensitive to differences in perceived phonetic goodness-of-fit to the native phonological category. If one of the non-native phones is perceived as a more acceptable instance of the L1 category than the other non-native phone, then it is a category-goodness assimilation and discrimination is predicted to be very good. If there is no difference in perceived phonetic goodness-of-fit between the two non-native phones then it is a single-category assimilation, and discrimination is predicted to be poor. For contrasts where one phone is categorized and the other is uncategorized, an uncategorized-categorized assimilation, discrimination is predicted to be very good. Discrimination should vary from poor to very good for uncategorized-uncategorized assimilations, depending on their phonetic proximity to one another and the perceived similarity to sets of native phonological categories.

A recent study has shown that non-native phones can be uncategorized in three different ways (Faris, Best, & Tyler, 2016). Focalized phones are perceived as weakly consistent with only one L1 category and clustered phones are those that are perceived as weakly consistent with multiple L1 categories. Dispersed phones are perceived as speech but are not perceived as similar to any native category. For uncategorized-categorized and uncategorized-uncategorized assimilations involving focalised and clustered phones, discrimination varies as a function of perceived phonological overlap between the sets of native categories that are weakly consistent with them, such that it is more accurate for non-overlapping contrasts than partially overlapping contrasts (Faris, Best, & Tyler, 2018). For contrasts involving dispersed phones, discrimination should be excellent for uncategorized-categorized assimilations, but for uncategorized-uncategorized assimilations discrimination should vary according to their phonetic proximity. It is only in that latter case that phonological learning from the native language would have minimal influence on discrimination. These discrimination predictions for dispersed phones are yet to be tested experimentally.

PAM-L2 uses PAM contrast assimilation types as a basis for predicting the likelihood of acquiring new L2 categories when a learner is actively acquiring the non-native language. Discrimination should improve when the contrast assimilation type changes as a result of new category acquisition (e.g., a category-goodness assimilation becomes a two-category assimilation). Best and Tyler (2007) clarified that perceptual learning could take place at multiple levels of attention focus, for example, phonological, phonetic, and gestural (see Strange, 2011, for complementary ideas about the role of attention in speech perception). For example, when each L2 phoneme in a contrast is perceived as a different L1 category (a PAM two-category assimilation), prior learning of an L1 phonological contrast serves for discrimination in the L2. Once learners begin to acquire an L2 vocabulary using those categories, they will have developed a common L1-L2 phonological category for each. If there is a discernible phonetic difference between the L1 and L2 versions, the perceived phonetic differences between them may become sharper over time. If the L1 and L2 version come to occupy separate regions of phonetic space within that L1-L2 phonological category, then the learners will have established separate L1 and L2 phonetic categories as part of a common L1-L2 phonological category. On the other hand, if the L1 and L2 versions are sufficiently similar to each other phonetically, then the learners will establish instead

a common L1-L2 phonetic category in both phonological *and* phonetic terms. Recall that in the case of a PAM two-category assimilation, the learner does not need to acquire any new phonological contrast in the L2. The likelihood of acquiring a new phonological category is low, in that case, because sensitivity to phonological contrast between existing L1 phonological categories serves perfectly well in the L2.

The cases presented by Best and Tyler (2007) focused on individual contrast assimilations (e.g., two category, category goodness) to show how predictions can be made for L2 learners on the basis of cross-language perceptual assimilation by naïve perceivers. For the sake of simplicity, the same approach will be taken here. It is important to note, however, that a phonology consists of systemic relationships between all phonological categories. Successful acquisition of a given L2 contrast shows that the learner can detect an L2 phonological distinction, but to be able to conclude that a new L2 category has been acquired it is necessary to establish that the new L2 phonological category: 1) forms two-category assimilations with all other L2 phonemes, and; 2) does not form a common phonological category with any L1 phoneme. For this reason, we advocate taking a whole-system approach to the study of L2 speech learning (Bundgaard-Nielsen, Best, Kroos, & Tyler, 2012; Bundgaard-Nielsen, Best, & Tyler, 2011a, 2011b), particularly for vowels, where participants are given the opportunity to categorise all of the vowel phonemes from the L2, and where they are provided with all possible vowel labels in the categorisation task (see, e.g., Faris et al., 2016, 2018).

Since PAM and PAM-L2 define phonological differences as those that are relevant to discriminating minimally contrasting lexical items, L2 vocabulary size is likely to play a key role in guiding perceptual learning in the L2 (for studies on lexically guided perceptual retuning see, Kraljic & Samuel, 2006; McQueen, Tyler, & Cutler, 2012; Norris, McQueen, & Cutler, 2003). Best and Tyler (2009) suggested that the window of opportunity for perceptual attunement may be quite early in acquisition, prior to the establishment of a large L2 vocabulary. According to *The Vocabulary-Tuning Model of L2 Rephonologization* (Bundgaard-Nielsen et al., 2011a), an increasing vocabulary drives perceptual reattunement to the L2 phonology. This idea was supported by Bundgaard-Nielsen, Best, and Tyler (2011a, 2011b), who showed that learners with larger vocabularies had more consistent categorisation of L2 phonemes than learners with smaller vocabularies. More consistent categorisation was associated with more accurate discrimination for some assimilation

types (e.g., uncategorised-categorised), but not for others (e.g., single category). An increasing vocabulary may support perceptual learning for contrasts that are more discriminable (e.g., uncategorised-categorised and uncategorised-uncategorised), but inhibit perceptual learning for those are less discriminable (e.g., single category). This raises the question of how many words constitutes a large L2 vocabulary. For children learning their L1, vocabulary acquisition is slow up to around 50 words and rapidly increases thereafter (see, e.g., Nazzi & Bertoncini, 2003). This would seem to suggest that learners should also aim to maximise their opportunities for phonetic learning before the L2 vocabulary exceeds 50 words.

L2 learners are most likely to acquire a new L2 phonological category for contrasts where both L2 phonemes are assimilated to the same L1 phonological category but with a perceived difference in phonetic goodness-of-fit (a PAM category-goodness assimilation), or where at least one of the L2 phones is uncategorized (PAM uncategorized-categorized or uncategorized-uncategorized assimilations). For the category goodness case, Best and Tyler (2007) speculated that the more deviant sounding phone might first be established as an L2 phonetic variant of a common L1-L2 phonological space within that category (with the more acceptable phone likely residing within a common L1-L2 phonetic category). As the learners tune in to the phonetic difference between the L2 phonemes, they would recognise that the perceived phonetic difference signals a meaning difference between minimally contrasting L2 words and a new L2 phonological category would be developed. For uncategorized phones, Best and Tyler suggested that they should be relatively easy to acquire as new L2 phonological categories. However, if the L2 phonemes in an uncategorized-uncategorized assimilation are phonetically similar, it is possible that they might not be differentiated from each other. In that case, a new L2 phonological category might be established that encompasses both (undifferentiated) L2 phonemes.

When both L2 phonemes are assimilated as the same L1 category, but there is no difference in phonetic goodness-of-fit (a single-category assimilation), the learners are unlikely to acquire a new L2 phonological category. Both will be incorporated into an L1-L2 phonological category and an increasing vocabulary will reinforce the equivalence. While this may seem unoptimistic, single-category assimilations are likely to pose a particular type of difficulty for the L2 learner, even with high-quality native-speaker input. Single-category assimilations may involve cases where the L1 not only lacks a phonological distinction to assist the learner, but one

where the degree of acceptable phonetic variability of the L1 phonological category encompasses the phonological contrast in the L2. That is, certain phonetic differences serve a lexical/functional purpose (*phonological distinctiveness*), but phonological categories remain unchanged across other phonetic differences (*phonological constancy*; see Best, 2015; Best et al., 2009). Take, for instance, the bilabial plosive-implosive distinction, /b/-/ɓ/, which English native perceivers assimilate as a single-category assimilation across a number of different languages (Ma'di: Antoniou, Best, & Tyler, 2013; Zulu: Best et al., 2001; Sindhi: Fenwick, Best, Davis, & Tyler, 2017). Both [b] and [ɓ] are possible allophones of /b/ in English (Ladefoged & Johnson, 2014), so it is possible that English native perceivers have a single phonetic category that encompasses both allophones. Regardless of the explanation for why certain L2 phonemes are assimilated as single-category assimilations, it is clear that they are very difficult to discriminate. It is likely that targeted perceptual training would be needed to learn to detect the difference between L2 phonemes in a single-category contrast.

Finally, it is worth considering how the predictions for uncategorized phones might be refined by taking into account the new uncategorized assimilations proposed by Faris et al. (2016, 2018). For contrasts involving dispersed assimilations, the predictions would be unchanged from those suggested by Best and Tyler (2007) for assimilations involving uncategorized phones. Those involving focalised or clustered assimilations, however, may have a different developmental path. If a contrast includes one of those assimilations, it means that the perceiver detects phonological similarity, albeit weakly, between the focalised or clustered phone and one or more L1 phonological categories. The likelihood of establishing a new L2 phonological category would depend crucially on the degree of perceived phonological overlap (Faris et al., 2018) between the L2 phonemes of a contrast, such that non-overlapping and partially overlapping contrasts are more likely to form separate L2 categories than completely overlapping contrasts. There is not enough experimental data available to predict specific outcomes for all contrasts involving at least one focalised or clustered phone, but it is possible to outline the range of possible outcomes. They are presented in Table 1. Note that in the cases where an uncategorised L2 phoneme is acquired as a common L1-L2 category, that would only be an optimal outcome if no other L2 phoneme had been acquired as the same L1 category.

Uncategorised-Categorised	Uncategorised-Uncategorised
• The uncategorised L2 phoneme is acquired as a new L2 phonological category	• Each uncategorised L2 phoneme is acquired as a new L2 phonological category
• The uncategorised L2 phoneme is acquired as a common L1-L2 phonological category with an L1 phoneme that is different from the categorised member of the pair	• A new L2 phonological category is acquired incorporating both L2 phonemes
• The uncategorised L2 phoneme forms a common L1-L2 category with the categorised member of the pair	• Both L2 phonemes are acquired as a common L1-L2 phonological category with a single L1 phoneme
	• Each L2 phoneme is acquired as a common L1-L2 phonological category with a different L1 phoneme
	• One L2 phoneme is acquired as a new L2 phonological category and the other is acquired as a common L1-L2 phonological category

Table 1. Possible category acquisition outcomes for contrasts involving at least one focalised or clustered uncategorised L2 phoneme.

To summarise, for PAM-L2 the likelihood of L2 phonological category acquisition is crucially dependent on how pairs of L2 phonemes are assimilated to the L1 phonological system. To have the opportunity to tune in to the phonetic differences that signal phonological contrast in the L2, learners need input that preserves those differences, and perceptual learning needs to occur prior to the establishment of a large L2 vocabulary. In the next section some of the characteristics of classroom FLA that may impact on L2 category acquisition, from a PAM-L2 perspective, will be outlined.

3. Factors affecting phonological category acquisition in the FL classroom

The principles of PAM-L2 were illustrated using the idealised situation of a learner previously naïve to the L2 in an immersion environment. Such a learning situation may be rare in the modern age, especially when the target

language is English, and people living in a predominantly L2 environment can vary considerably in their degree of exposure to the L2 on a daily basis (Flege & MacKay, 2004). It is useful, therefore, to consider the ways in which models such as PAM-L2 might be applied to other possibly more common L2 learning situations, such as classroom FLA. Broadly, the conditions for optimal phonological attunement, according to PAM-L2, are those where learners have an opportunity to tune in to L2 phonological contrasts prior to the acquisition of a large L2 vocabulary. The idealised L2 learner whose first and continuing exposure to the L2 is in an immersion environment with rich native-speaker input would have ample opportunity for the sort of perceptual learning that is required. However, classroom FL learners may not have the same opportunities and the context of classroom FLA may change the predicted outcomes. Here, three aspects of classroom FLA will be considered: spoken language input, written language input, and previous FL exposure. This will be followed by a reconsideration of PAM-L2 predictions as applied to classroom FLA.

3.1 Spoken language input

In the FL classroom, interactions in the L2 are likely to be with foreign-accent speech. In most cases the teacher is likely to speak the target language as an L2, and with a non-native accent. Students in class will also speak to each other in class during activities, presumably with a non-native accent. This differs from the idealised immersion situation, where the learner is exposed to native-speaker input. Note that accented speech is not necessarily an impediment to the acquisition of new L2 categories. If the accented speech maintains a phonological distinction between all L2 phonemes, and native speakers unambiguously perceive them as intended, then the learners may acquire all necessary phonological distinctions in the L2. Their perception would be accented (Jenkins et al., 1995), but if a phonological distinction has been acquired, then the learners may be able to fine tune that distinction at some point in the future with exposure to rich L1 input. On the other hand, if the accented speech does not maintain certain phonological distinctions then this would clearly reduce the likelihood of learners acquiring them. Minimally contrasting words would be homophonous, this would be reinforced with an increasing vocabulary, and it may fossilize even if the learner is exposed to rich L1 input in the future. In short, it is not necessarily a lack of *native-speaker* input that may reduce the likelihood of L2 category acquisition in the classroom, but input that fails to provide clear phonological differences between L2 categories.

3.2 Written language input

Another key difference between L2 immersion and classroom FLA is the use of written language to teach vocabulary and grammar. Speech is transient, whereas the written word is permanent (Ehri, 1984, 1985), so written materials are an excellent resource for learners to revise and consolidate what has been learned in class. However, written materials provide the opportunity to acquire a large L2 vocabulary in a short period of time, and this may reduce the window of time available for perceptual learning of L2 phonological contrasts that are difficult to discriminate (e.g., single-category assimilations). Alphabetic writing systems or *orthographies*, also provide a (sometimes imperfect) representation of the phonology of a language. Each time learners read a word in the L2 they may be reinforcing a phonological structure for that word that is based on L1 grapheme-phoneme correspondences that have been adapted to the L2. For contrasts where learners can perceive a phonetic difference between the L2 phonemes, it is conceivable that alphabets might help learners to focus on and tune in to those phonetic differences in speech, as long as the L2 orthography signals a clear phonological difference. However, in cases where the orthography does not signal a clear phonological difference, their internal rehearsal of the pronunciation of L2 words via orthography may reinforce a perception that the L2 phonemes are equivalent rather than distinct.

3.3 Previous FL exposure

Whereas PAM-L2's predictions are based on an immersion learner with no previous experience with the L2, students in FL classrooms may vary greatly in their degree of previous exposure to the language. This could be in the form of prior classroom instruction, exposure to films and television, study abroad, family, or any number of other influences (Bohn & Bundgaard-Nielsen, 2009). They may also have learned to read the L2, especially if it shares the same writing system as the L1. If words had been learned in the absence of spoken input, the learner may already have applied the L1 phonology to a large vocabulary of L2 words via orthography. This is important for all models of L2 speech learning, but it is crucial for PAM-L2 because initial experience with the L2 sets the trajectory for perceptual learning. A learner with previous L2 experience may already have acquired a category-goodness contrast as a single common L1-L2 category, for example. Fossilisation may already have begun to occur, due to an increasing L2 vocabulary, making it more difficult to acquire the

less acceptable version as a new L2 phonological category than PAM-L2 would generally predict. Furthermore, predicting category acquisition is made even more difficult when learners have been exposed to a different range and variety of regional and foreign accents (Bohn & Bundgaard-Nielsen, 2009). Differences in prior FL experience are not only a problem for evaluating PAM-L2's category acquisition predictions in a classroom context. It is also important to consider from a pedagogical standpoint because learners may benefit from different classroom learning experiences as a function of their prior exposure.

3.4 PAM-L2 category acquisition predictions in an FLA context

Taking these three aspects of classroom FLA into account, it is now possible to outline how the PAM-L2 predictions might change for the classroom FL context. There is no change to the predictions for two-category assimilations. L2 learners have all the phonological sensitivity they need from the L1 to learn vocabulary with L2 phonemes that form two-category assimilations with all other L2 phonemes. Category-goodness assimilations are less likely to be acquired in the classroom than via immersion, especially if there is little phonetic difference between the L2 phonemes in L2-accented spoken input, or the student internally rehearses the words on the basis of their written form. Perceptual learning of the phonetic distinction may be curtailed by rapid vocabulary acquisition, especially via the written medium. If single-category assimilations are unlikely to be acquired in the immersion case, then they are even less likely to be learned in the classroom! Acquisition of dispersed uncategorised L2 phonemes is unlikely to be inhibited by classroom FLA. It is even possible that they may be learned successfully, and very rapidly, if there is sufficient spoken input and the L2 orthography provides unambiguous information about the phonological contrasts involving that L2 phoneme. As it is not yet clear how clustered and focalised L2 phonemes are acquired in the immersion case, it is difficult to specify how classroom FLA would alter their development. It is possible that the reduced exposure to native speaker input in FLA versus L2 acquisition might increase the likelihood of acquiring the uncategorised L2 phoneme as a common L1-L2 phonological category, whereas the provision of unambiguous orthographic information might provide a focal point for the learner to tune in to the phonetic properties and establish a new L2 phonological category.

4. Testing phonological category acquisition in the FL classroom

There are certain methodological requirements for testing PAM-L2 predictions. As with any study testing PAM, it is essential to include a categorisation task with goodness rating. For example, in cross-language speech perception studies, participants are usually presented with a consonant or vowel in a carrier frame (e.g., consonant + /a/ or /h/ + vowel + /bə/) and they select a native category label that best matches the non-native phone. Next, they rate how acceptable a version the non-native phone is of the category that they chose. Without including the goodness rating step, it is not possible to distinguish between single-category and category-goodness assimilations. To test PAM-L2 predictions, it is necessary to determine whether a new L2 phonological category has been acquired, but Best and Tyler (2007) did not address the question of how category acquisition can be determined. As there is no direct link between perception and production for PAM-L2, learners' productions of the L2 category does not necessarily provide accurate information about whether that category has been acquired in perception. For example, an L2 learner could be trained to articulate a pair of contrasting L2 phonemes without necessarily being able to discriminate them. In recent work in our lab, we have had participants complete two categorisation tasks with the same L2 speech stimuli, one using L1 labels and the other using L2 labels, (Faris, Best, & Tyler, in preparation; San & Tyler, in preparation). By comparing categorisation across the two tasks it should be possible to infer whether a new category has been acquired. For example, an L2 phoneme that is uncategorised in the L1 and categorised in the L2 would seem to be a clear case of L2 category acquisition. We chose to use separate categorisation tasks for each language, rather than a single task with labels from both languages, because results of a single task would be difficult to interpret. If an L2 phoneme has been acquired as a common L1-L2 category, a given participant may only ever choose either the L1 or L2 label, or a mixture of both. Categorising in terms of L2 labels only would also be inadequate because the researcher would be unable to exclude the possibility that all L2 phonemes had been acquired as common L1-L2 categories. Ideally, tests of categorisation should be accompanied by tests of discrimination. If an L2 category has been acquired, and, for example, a contrast that was category goodness at the initial stage of learning has become a two-category assimilation, then discrimination should have improved.

One challenge with this approach is that categorisation is a metalinguistic task. Labelling in terms of L1 phonological categories requires phonemic awareness, which is learned as a by-product of alphabetic literacy (Ehri, 1984, 1985; Read, Zhang, Nie, & Ding, 1986; Tyler & Burnham, 2006). Performing a categorization task can be challenging even in the L1, especially for vowel labels in English where the orthography does not provide a one-to-one mapping between graphemes and phonemes (see, e.g., Faris et al., 2018; for a discussion, see Flege, 2003). Asking L2 learners to perform a metalinguistic task with L2 labels is even more challenging, and the data obtained may be inherently noisier than data obtained using L1 labels. Clearly, learners cannot perform an L2 categorisation task until they reach fairly high levels of proficiency in the L2. To be able to make any conclusions about category acquisition in a cross-sectional study, it is essential to include a control group of naïve listeners to establish a baseline for perceptual assimilation among the L1-speaking population. Studies could employ a categorisation task using L1 labels for the control group, to determine perceptual assimilation patterns prior to L2 learning, and a combination of L1 and L2 categorization tasks with the learner group to probe L2 category acquisition.

It could be argued that differences or changes in discrimination accuracy could be used instead as evidence for L2 category acquisition. Improvements in discrimination are certainly evidence of learning, but they do not provide direct evidence for category acquisition. For example, an improvement in discrimination could occur because a new L2 category has been formed for both L2 phonemes in an uncategorised-uncategorised assimilation, or because both were acquired as common L1-L2 categories with different L1 phonological categories. Without a categorisation task, it is not possible to differentiate these alternatives. For some researchers and educators, showing an improvement in discrimination may be sufficient, especially to evaluate a targeted classroom intervention. However, the benefit of using a theoretical framework, such as PAM-L2, is that it can *explain* why certain contrasts are easier to learn than others. Classroom interventions based on PAM-L2 would be focused on supporting the detection of new L2 phonological contrasts, so that all L2 phonological contrasts become two-category assimilations, which should then lead to improved discrimination. Without a theory that links perceptual learning of phonological contrast with discrimination accuracy, it may difficult to explain why discrimination of certain L2 contrasts improves more than others. If using PAM-L2 as a framework, researchers should aim to include

a range of perceptual assimilation types (e.g., single category, category goodness, and uncategorised-categorised) to provide opportunities for observing differences in category acquisition, and variable improvements in discrimination.

It is also necessary to account for each learner's experience with the L2 prior to participating in the experiment. To overcome the problem of learners' prior experience, the best solution is to include only those participants with no prior exposure to any language other than the L1 (i.e., a functional monolingual), and to follow their language development longitudinally. However, such strict inclusion criteria may be an impediment to many researchers, especially those working in English FL classrooms. Some researchers may choose to compromise by including participants without prior formal instruction or immersion experience, but who may have had incidental exposure through television, film, or a short holiday in an environment where the L2 is spoken. Others may have no choice but to include participants with a range of prior learning experiences. The more prior experience the participants have had with the L2, the greater the requirement to also take into account covariates that might affect the initial state of the L2 phonology prior to formal instruction (e.g., extended time spent in a country where the L2 is spoken, L2 vocabulary size, watching television or movies in the L2 that have not been dubbed). Even if covariates are taken into account in statistical analyses, it is important to acknowledge the consequences of relaxing the inclusion criteria for testing theoretical predictions. Comparisons of learner groups and monolingual controls, or performance over time in a single learner group, are likely to be heavily influenced by experience of the learners prior to entering the classroom. Failure to observe category acquisition could be due to fossilisation, and successful acquisition in class could equally be due to the perceptual learning trajectory that was set by prior L2 exposure. Some of the variability in the initial state of the learner may be taken into account by forming subgroups of participants based on their individual perceptual assimilation patterns (see, e.g., Tyler, Best, Faber, & Levitt, 2014). That is, if some participants perceive a given contrast as a single-category assimilation, while others perceive it as category goodness, then the latter subgroup might be more likely than the former to acquire a new L2 category. Should that turn out to be case, then this would possibly open up new avenues for assessing students prior to formal instruction, and tailoring learning experiences to their specific needs.

5. Possible ways to incorporate PAM-L2 principles into FL learning curricula

The detection of phonological contrast is important for communication in the L2. Just as intelligibility is important for communication in L2 production (Munro, 2008), the inability to distinguish L2 phonemes can have implications for processes of L2 word recognition that extend beyond the homophony of minimal-pair words (see Cutler, 2012). Recognising words in continuous speech involves processes of competition between candidate words. For example, the English phrase "ship inquiry" (/ʃɪpɪŋkwaɪəri/ contains the candidates *ship*, *shipping*, *ping*, *pink*, *ink*, *inquire*, *inquiry*, *choir*, *why*, and *wire*, among others, and quite a few fragments of words that are partially activated and excluded as the words unfold (e.g., **ship***wreck*, **include**, **quie***t*) (Norris, 1994). It is not difficult to imagine how the pool of candidates would increase if certain contrasts were not able to be discriminated. If a learner was unable to discriminate English /s/-/ʃ/ and /i/-/ɪ/, then the candidates *see*, *she*, *seep*, *sip*, *sheep*, *sipping*, *seeping,* and *pea* would be added to the list, along with many additional word fragments. A further consequence of this is that unresolved competition between candidate words lasts longer in L2 listening than in L1 listening (Weber & Cutler, 2004). This means L2 comprehension involves a higher cognitive load than L1 comprehension when the L2 user cannot discriminate certain L2 contrasts. Proficient L2 users may be able to use prior knowledge of communicative situations to reduce cognitive load (Tyler, 2001), but if L2 learners were able to acquire phonological contrasts early in L2 acquisition, then their L2 vocabulary should support a more efficient word recognition system.

To incorporate PAM-L2 principles in the classroom, perceptual assimilation to the L1 needs to be taken into account in FL curricula, and learners need to have opportunities for tuning in to the phonetic differences that signal phonological contrast in the L2 prior to the acquisition of a large L2 vocabulary. Suggestions already provided by Piske (2007) resonate with this idea – students should be exposed to high quality input and there should be opportunities for perceptual training. Below are some suggestions that elaborate on those ideas from a PAM-L2 perspective, and which also consider the issue of vocabulary acquisition.

5.1 Ensure students are exposed to L2 phonological contrast
Exposure to rich and varying speech from native speakers may be important for L2 acquisition (Piske, 2007), but this may not always be

possible to provide in an FL classroom. Students in class need to practise communicating with each other in the L2 to be able to use the language in real-life situations, so accented speech certainly cannot be avoided entirely. Nevertheless, teachers should ensure that students have as much exposure as possible to L2 speech that unambiguously preserves a phonological contrast between all phonemes in the target accent of the L2. They should also explain the importance of learning to perceive the differences between L2 phonemes for ease of L2 word recognition. If teachers reliably produce a phonetic difference between L2 phonemes (i.e., that native speakers of the L2 detect as a phonological contrast), then they can confidently model pronunciation for the class and supplement their exposure with audio(visual) materials of authentic native speaker productions. On the other hand, if they do not reliably produce a distinction, then audio(visual) materials should be used, and they should avoid modelling pronunciation of words with confusable L2 phonemes. To be clear, it is not L2-accented input that needs to be avoided – it is input that fails to provide clear phonetic differences between contrasting L2 phonemes. The beginner stages of learning are crucial for perceptual learning. The acquisition of L2 vocabulary that does not preserve L2 phonological contrast may set the learner on a trajectory that is difficult to remediate at a later stage of learning.

5.2 Provide opportunities for perceptual training
Time in class should be devoted to perceptual training of single-category, category-goodness, uncategorised-categorised, and uncategorised-uncategorised assimilations (see also Piske, 2007). There is a long history of high variability training studies that have shown improvements in identification of minimal pair words when feedback is provided and the stimuli are spoken by multiple speakers (e.g., Bradlow, Akahane-Yamada, Pisoni, & Tohkura, 1999; Iverson, Pinet, & Evans, 2012; Logan, Lively, & Pisoni, 1991). High variability perceptual training could be conducted in class, or as self-study using a computer-based approach. Additionally, activities designed to draw students' attention to phonological contrasts in the context of L2 pronunciation teaching may be adapted for this purpose (for reviews see Gurzynski-Weiss, Long, & Solon, 2017; Mora & Levkina, 2017). The crucial time for perceptual training is at the early stages of learning, prior to the establishment of a large L2 vocabulary.

For effective perceptual training, it is necessary to know how L2 consonants and vowels are assimilated by the students. In classrooms where all students have the same L1, existing cross-language speech perception

studies may provide sufficient information about how the L2 phonemes are likely to be assimilated. However, there are individual differences in perceptual assimilation, and many classrooms have students from diverse backgrounds. To obtain a clear picture of how students' L1s might influence L2 speech perception, teachers may consider including tests of perceptual assimilation as part of the initial student diagnostic tests that are often used to gauge a student's level. This would allow perceptual training to be tailored to the individual beginner student's needs and identify areas for remediation for more advanced learners.

5.3 Take perceptual assimilation into account when introducing L2 vocabulary

To the extent that it is possible without becoming artificial, early vocabulary should preferentially include words that are easily discriminable using common L1-L2 categories, and words involving uncategorised phones. Words involving single-category assimilations, or the less-good phoneme of a category-goodness assimilation, should be introduced slowly and incorporated into perceptual training regimes. This should give students an opportunity to tune in to the phonetic differences that signal the phonological contrast before the vocabulary becomes too large. In addition to learning words for meaning and context, students should be given frequent opportunities to compare the pronunciations of groups of words containing one L2 phoneme with other groups of words containing a contrasting L2 phoneme. Obviously, there are many other factors that determine the order that vocabulary is introduced, but with an awareness of perceptual assimilation as a factor when designing curricula, it may be possible to delay the introduction of many words to allow more time for perceptual learning before the vocabulary becomes too large.

5.4 Delay introduction of orthography and/or teach the phonetic alphabet

Students whose L1 is alphabetic are likely to apply L1 grapheme-phoneme correspondences when reading L2 words (e.g., Escudero, Simon, & Mulak, 2014; Hayes-Harb, Nicol, & Barker, 2010), which may inhibit optimal L2 phonological development. Delaying the introduction of orthography for as long as possible should increase the window of time available for tuning in to the phonetic differences that define L2 phonological contrasts. Also, delaying the introduction of orthography may be key to managing the rate of vocabulary growth. Many students may be frustrated if they

are not given the spelling for newly acquired vocabulary so it would be important to explain the importance of tuning in to phonological contrasts and how delaying spelling may support that. An additional solution may be to introduce an orthography that provides a one-to-one correspondence between phonemes (or allophones) and graphemes, such as the International Phonetic Alphabet (IPA). This would promote an awareness of phonological differences that are difficult to perceive, and it may provide a point of focus to help students to learn the phonetic differences between L2 phonemes. Vocabulary would still need to be introduced slowly, but once the student has learned a certain number of words using the phonetic script (e.g., 50 words), the L2 orthography could be introduced for words already learned. Any new words learned subsequently would be acquired with both the phonetic script and the L2 orthography to ensure that the learner is aware of the correct phonological form. Teaching IPA at the beginner stage would also open up possibilities for tracking perceptual assimilation over time, because IPA symbols could be used instead of regular orthography and keywords in L2 categorisation tasks. They could also be used in perceptual training tasks to focus attention at the phonemic level rather than using identification of minimal-pair words, which requires the acquisition of new vocabulary, and as diagnostic tests to track students' phonological development.

6. Summary and conclusions

PAM-L2 bases its predictions about L2 category acquisition on the pattern of perceptual assimilations of L2 phonemes to the L1 phonological system at first contact with the L2. For optimal L2 perception, the learner needs to detect a phonological contrast between each L2 phoneme and all other L2 phonemes. This can be achieved using existing L1 phonological categories, which become common L1-L2 categories, or by establishing new L2-only phonological categories. A new L2 phonological category is most likely to be acquired for the less-good version of a category-goodness assimilation, or for an uncategorised L2 phoneme. The likelihood of acquiring a new L2 phonological category is crucially dependent on the learner having opportunities for perceptual learning at an early stage of language acquisition. The perceptual learning should occur prior to the establishment of a large L2 vocabulary, especially for contrasts where learners have poor discrimination accuracy (i.e., single category assimilations and contrasts involving overlapping uncategorised L2 phonemes). If learners can already detect a clear phonetic difference between contrasting L2 phonemes

(i.e., contrasts involving non-overlapping or dispersed uncategorised L2 phonemes) then perceptual learning should be rapid. An increasing L2 vocabulary and unambiguous grapheme-phoneme correspondences may support further attunement, provided that the spoken input preserves the phonological properties of the contrast.

While PAM-L2's predictions were formulated with an immersion context in mind, there are no qualitative differences in the predictions when they are applied to the FL classroom. However, the likelihood of new category acquisition would be generally lower in the classroom than in an idealised immersion environment because of fewer opportunities for perceptual learning of L2 phonological contrast prior to the acquisition of a large L2 vocabulary. All of the suggestions made by Piske (2007) would certainly improve the likelihood of category acquisition in the classroom. Applying the principles of PAM-L2, the likelihood may be further improved by: 1) ensuring that learners are exposed to clear phonological differences for all L2 contrasts; 2) providing perceptual training at the beginner level for single-category, category-goodness, uncategorised-categorised, and uncategorised-uncategorised assimilations; 3) taking perceptual assimilation into account when introducing new vocabulary, and; 4) managing the introduction of written forms of words.

Optimal L2 phonological acquisition is a desirable outcome for the L2 learner, but the theoretically inspired suggestions made here clearly do not take into account the practicalities of classroom-based FLA. It is acknowledged that some of the suggestions may be impossible to achieve in certain FL contexts. For example, some language schools may enrol students for only short periods of time, they may not offer classes for absolute beginners, or they may have limited hours of face-to-face teaching, making it impractical to introduce time-consuming activities such as perceptual training and teaching IPA script. Given the widespread teaching of English throughout the world, it may be that these suggestions are more feasible for other L2 target languages where students are more likely to be naïve at the onset of learning. Before these theoretical suggestions can be put into practice, more research is required to test whether perceptual training prior to large vocabulary acquisition results in improvements over the longer term. Researchers at universities with a mandatory foreign language requirement would seem to be well placed to conduct such a study.

Even without direct empirical evidence for the specific suggestions made here, it is clear from previous research that perceptual assimilation to the L1 has a strong influence on L2 speech perception. Some L2 contrasts

are easy to discriminate at the onset of FL learning, while others are very difficult indeed. The input that students receive in the classroom (and outside of class) is crucial for setting their perceptual learning trajectories. Even if it is not possible to implement curriculum-based strategies to support phonological acquisition, students should be made aware of those contrasts that are likely to cause difficulty in the L2. Motivated students who seek opportunities to "train their ears" outside of the classroom may benefit from less effortful L2 comprehension when they progress to an advanced level of L2 acquisition.

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