When perceiving spoken language, listeners must contend with extensive variability in the speech input, from differences in vocal tract size to the presence of a speech impairment or foreign accent. Moreover, real-world communicative exchanges often occur in adverse listening conditions, such as in the presence of background noise, introducing additional non-linguistic information into the signal. This rampant acoustic variability can present a challenge for speech comprehension. My research has centered on how we are able to successfully accommodate this variability during speech perception. To that end, my work has focused on two primary research areas: 1) how listeners perceive and encode information in their auditory environment during speech perception in different listening conditions, and 2) how listeners’ perceptual systems adapt to new or unusual speech productions. I have looked at this through the acquisition of non-native sounds as well as through adaptation to foreign-accented speech. In particular, I have been interested in how short-term (e.g., background noise, talker variability) and long-term perceptual experiences (e.g., linguistic background, musical training) shape perception and learning.

**Perception and encoding of speech and non-speech information**

Successful speech comprehension requires listeners to match the incoming auditory input to the appropriate linguistic representations stored in memory. This can be a complex process, as individual instances of a given word will vary as a result of situation-specific characteristics (e.g., talker, noise). While traditional models of spoken word recognition have posited that linguistic processes operate over purely abstract linguistic representations, there is a growing body of research suggesting that context-dependent non-linguistic information (e.g., gender, talker identity) is perceptually integrated and encoded with linguistic information during speech processing. This work has focused predominantly on the influence of speech-intrinsic information (e.g., gender, talker identity) on speech processing (e.g., Goldinger, 1996), proposing that listeners encode episodic details of the perceptual speech context into, or along with, representations of lexical items. Collaborative work conducted during my Ph.D. investigated the extent and limits of the influence of co-occurring non-linguistic acoustic information, both speech-intrinsic (talker identity) and speech-extrinsic (background noise), on the perception and encoding of spoken language.

In Cooper et al. (2015), we used several different behavioral methodologies to probe this issue, including a speeded classification task and a continuous recognition memory task, and also manipulated whether the noise was spectrally-overlapping or spectrally-segregated from the speech signal. Results revealed an interdependence of perceptual processes used to encode information about noise with talker identity, at a relatively early stage of perceptual processing. Cooper & Bradlow (under revision) further explored the integral encoding of context-specific auditory characteristics with linguistic information by examining native (L1) and second language (L2) listeners’ explicit memory in a delayed recognition memory paradigm. Results revealed that listeners form integrated cognitive representations of both talker and noise information, even when the two auditory streams are spectrally non-overlapping. Additionally, linguistic background and lexical characteristics were found to interact to modulate the magnitude of these exemplar specificity effects, which may arise from attentional differences during encoding. This line of research contributes to a more comprehensive understanding of the cognitive and linguistic consequences of speech perception in adverse listening conditions.

In ongoing post-doctoral work, I am investigating the influence of talker information on spoken word recognition in adults and young children. Here, toddlers (30-36 month olds) and their mothers are asked to recognize a set of words, containing their own productions (recorded 2-4 weeks prior) and those of an unfamiliar child and their mother. Such work will inform our understanding of the relationship between perception and production, and, in particular, the influence of indexical information and talker familiarity on speech perception.

Research Statement
Angela Cooper
Perceptual learning

In addition, I have also examined how listeners accommodate novel or variable sound categories, and the influence that listeners’ perceptual experiences have on learning.

Second language acquisition. One avenue through which I have investigated this issue is the perception and acquisition of new phonemic categories and lexical items. Adult second language listeners face a host of well-documented challenges, with a variety of factors (e.g., linguistic background, musical experience, age of acquisition) influencing the ease with which non-native phonemic contrasts are acquired (e.g., McAllister, Flege & Piske, 2002). My research seeks to shed light on how the linguistic system accommodates incoming novel contrasts and how linguistic and non-linguistic experience shapes this process.

In Cooper and Wang (2012), I examined the relative and combined influences of linguistic and musical experience in learning to identify words contrasted by Cantonese lexical tones, accomplished by testing English and Thai musicians and non-musicians in a multi-session training paradigm. I investigated these factors in the context of both tone identification as well as word learning tasks, allowing for an examination of these factors’ roles in lower- and higher-level processing contexts. Findings from the tone identification task revealed that musicianship rather than prior tone language experience significantly influenced overall success. However, prior experience with musical (English musicians) or linguistic pitch (Thai non-musicians) resulted in higher proficiency in the word learning task relative to listeners without experience with either (English non-musicians). The combination of musical and linguistic pitch experience (Thai musicians) did not result in an additional advantage. These results support an integrated model of speech processing, as both language-specific experience (from L1 tonal background) and general acoustic tonal experience (from musical training) had an impact on word learning. This predicted that providing listeners with tonal experience in one of these domains (linguistic or musical) should boost performance in tone word learning. Follow-up work (Cooper & Wang, 2013) examined this prediction by providing language-specific tonal experience for English non-musicians, in the form a short-term lexical tone training task, prior to the word learning paradigm (from Cooper & Wang, 2012). Indeed, tone training served to heighten listeners’ tonal awareness, resulting in enhanced word learning proficiency relative to non-musicians who had not undergone tone training.

I have extended my investigations on the impact of musical experience on speech processing to the perception of a non-native temporal contrast (Thai vowel length) at varying speaking rates (Cooper, Wang & Ashley, in press). English musicians patterned similarly to native Thai listeners, demonstrating higher accuracy at identifying and discriminating between-category vowel length distinctions than at discriminating within-category durational differences due to speaking rate variations. English musicians also outperformed non-musicians at between-category vowel length discriminations across speaking rates, demonstrating musicians’ superiority in perceiving categorical phonemic length differences. These results provide the first evidence that musicians’ attunement to rhythmic and temporal information in music can transfer to facilitating their ability to normalize contextual quantitative variations (due to speaking rate) and perceive non-native temporal phonemic contrasts.

Adaptation to accented speech. The acquisition of a second language typically involves the introduction of novel sound categories; however, listeners must also accommodate variable exemplars of native sound categories that they encounter during native language processing. To handle this variability, effective human communication requires perceptual adaptation, with the perceptual system tracking distributions of information in the speech input and making adjustments as necessary to stored linguistic categories. Prior research has posited that lexical knowledge is what predominantly facilitates this adaptation process, with listeners comparing atypical pronunciations with stored word representations (e.g., Norris et al., 2003). However, it would be problematic if the
perceptual system adjusted its categories every time it encountered an unusual sound, as these categories would then include irrelevant pronunciations (e.g., speech errors), which would increase ambiguity between categories and so potentially impair speech recognition. For this reason, the system is hypothesized to maintain a certain degree of stability (Samuel & Kraljic, 2009), with adaptation only occurring when the system has sufficient evidence to do so. Given that the perceptual system must maintain a balance between stability and plasticity, what are the conditions under which the system will adapt?

In my dissertation work, I challenged the notion that lexical knowledge is the primary source of evidence for guiding perceptual adaptation (e.g., Davis et al., 2005; Maye et al., 2008; Norris et al., 2003) by examining the contribution of other levels of linguistic information on adaptation to foreign-accented speech in noise. To investigate this issue, I manipulated the type of auditory feedback presented to adult listeners, where the degree of match between the target and feedback sentences varied on sub-lexical, lexical and syntactic levels. I hypothesized that listeners can use knowledge of phonemes, syntactic and prosodic structure to facilitate adaptation, which my findings supported. For example, when attempting to understand a foreign-accented target sentence such as “The children dropped the bag”, listeners were equally facilitated when they were subsequently presented with a native-accented production of the same sentence, informing them of the lexical content of the target, as with an unrelated feedback sentence “The wife helped her husband”, providing them target-feedback connections on non-lexical levels of representation (Cooper & Bradlow, under revision), such as sentence prosody and sentence structure.

I also investigated how linguistic experience influenced the extent to which listeners adapted to a novel English accent and generalized their learning to unexposed accent patterns. Monolingual English (L1) and Dutch-English bilinguals (L2) were exposed to an artificial accent (e.g., /z/-to-/s/ yielding “sice” instead of size; Cooper & Bradlow, in prep), containing controlled accent deviation patterns with sounds that were either contrastive or not in Dutch. Following accent exposure combined, listeners completed lexical decision and word identification tasks with items containing trained accent patterns as well as items with untrained, structurally-related accent patterns. Both groups of listeners demonstrated adaptation and were found to generalize their knowledge to an untrained talker and untrained accent patterns in certain contexts. This kind of generalization suggests that adaptation mechanisms target features or sets of sounds categories rather than specific categories heard in exposure. Furthermore, the extent to which adaptation occurred was found to be modulated by the status of the accented segments in the listeners’ native language, with L2 listeners only adjusting categories that were contrastive in their L1.

Future research will build upon this line of work by examining how listeners initially acquire and continue to employ these perceptual adaptation mechanisms. I am currently investigating whether the perceptual system will utilize different adaptation strategies depending on the type of accented exposure they receive and their accumulated linguistic knowledge. I examine in both children and adults: 1) how distance from listeners’ own accent affects adaptation strategies to familiar words, 2) how accent inconsistency impacts adaptation strategies, and 3) how lexical variation during accent exposure influences adaptation. Finally, I will also investigate how exposure to accent variability in a toddler’s home environment affects adaptation to a novel accent. By examining the developmental trajectory of adaptation mechanisms, this work will provide insight into the question of how children can create mental abstractions from relatively limited input.
References