Word Recognition by English Monolingual and Mandarin-English Bilingual Speakers in Continuous and Interrupted Noise

Reconnaissance des mots dans le bruit continu et le bruit interrompu par des locuteurs unilingues anglais et des locuteurs bilingues mandarin-anglais

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Abstract

Word recognition in quiet and noise was examined with Mandarin-English bilingual and American English monolingual young adults (*N* = 24). The speech stimuli were Northwestern University Auditory Test No. 6 monosyllabic words. The competing stimuli were continuous and interrupted noises presented at three signal-to-noise ratios (i.e., 10, 0, and -10 dB). The noises had identical power spectrums and differed in their temporal continuity. In quiet, English participants performed significantly better than the bilingual participants. In noise, performance deteriorated as signal-to-noise ratio decreased and was poorer in the continuous noise. Bilinguals had poorer word recognition than monolinguals. The "release from masking" displayed by the bilinguals in interrupted noise, however, was equivalent to the monolinguals. One can infer that temporal resolution ability, as indexed with a measure of release from masking with this word recognition in noise paradigm, is independent of linguistic exposure.

Abrégé

Nous avons examiné la reconnaissance des mots dans un contexte silencieux et dans le bruit par de jeunes adultes bilingues parlant le mandarin et l'anglais et unilingues parlant l'anglais américain (N = 24). Les stimuli choisis étaient les mots monosyllabiques du Northwestern University Auditory Test No. 6. Les stimuli concurrentiels étaient des signaux de bruit continu et interrompu présentés à trois rapports signal-bruit (10, 0 et -10 dB). Les bruits avaient des spectres de puissance identiques, mais une continuité temporelle différente. Dans le contexte silencieux, les participants anglophones ont démontré un rendement significativement meilleur que les participants bilingues. Dans le bruit, la performance s'est détériorée à mesure que nous réduisions le rapport signal-bruit, et les résultats dans le bruit continu étaient inférieurs. Les personnes bilingues avaient une moins grande reconnaissance des mots dans le bruit que les personnes unilingues. Toutefois, l'effet de « relâchement du masquage » chez les personnes bilingues dans le contexte du bruit interrompu était équivalent à celui chez les personnes unilingues. On peut donc conclure que la capacité de résolution temporelle, telle que répertoriée par la mesure de l'effet du relâchement du masquage dans cette tâche de reconnaissance des mots dans le bruit, est une capacité non liée à l'exposition linguistique.

Bilingual (BL) listeners typically achieve a similar level of recognition of their second language (L2) in quiet relative to monolingual (ML) listeners. Under degraded listening conditions, both BL and ML listeners' speech recognition deteriorates. However, when perceiving L2 stimuli, BLs are disproportionately more affected by noise compared to MLs of that language (Cooke, Garcia Lecumberri, & Barker, 2008; Garcia Lecumberri & Cooke, 2006; Gat & Keith, 1978; Kang, 1998; Mayo, Florentine, & Buus, 1997; Nabelek & Donahue, 1984; Rogers, Lister, Febo, Besing, & Abrams, 2006; Shimizu, Makishima, Yoshida, & Yamagishi, 2002; Takata & Nabelek, 1990; Van Engen & Bradlow, 2007). Stationary noises and/or multi-talker babbles in the first language (L1) or L2 have been typically employed as competitors in these studies.

It has been suggested that the listening difficulty BLs experience with their L2 in noise is related to their limited linguistic exposure to the L2. Specifically, factors affecting BLs' perception of L2 include age of acquisition of L2 (Mayo et al., 1997; Meador, Flege, & Mackay, 2000), continual use of L2 in an L2 environment (Jia, Strange, Wu, Collado, & Guan, 2006; Meador et al., 2000), and L1 interference with L2 (Iverson et al., 2003; Van Engen & Bradlow, 2007). Further, speaker-independent factors (e.g., listening context and lexical frequency) may also contribute to BL listeners' difficulty in perceiving L2 (Levi, Winters, & Pisoni, 2007). Generally, early BLs (i.e., those who begin learning L2 as children) have better perception of L2 in noise than late BLs (i.e., those who begin learning L2 as adolescents or adults; Mayo et al., 1997; Meador et al., 2000). BLs with longer exposure of L2, or those that use L2 more often, perform better in recognizing L2 in noise (Gat & Keith, 1978; Jia et al., 2006). It has also been found that linguistic interference from L1 is more evident when L1 and L2 differ significantly in the listener's phonological system (Iverson et al., 2003; Tong, Francis, & Gandour, 2008; Van Engen & Bradlow, 2007).

Cutler, Weber, Smits, and Cooper (2004) suggested that compared to their L1 perception, BL listeners' L2 perception in noise is disproportionally poorer than that of native listeners because they are slower and less accurate at all speech processing levels (e.g., phoneme identification, segmentation, lexical recognition, syntactic processing, semantic processing, etc.) of L2 relative to their L1. The relative perceptual advantage for native versus non-native speech perception is believed to be a consequence of linguistic experience (i.e., years of exposure to a language) as well. That is, linguistic experience shapes an individual to perceive one's L1 with the greatest competence (e.g., Pisoni, Lively, & Logan, 1994). It is well recognized that linguistic experience mediates changes in development and maturation of the central auditory system. For example, as early as six months, infants have developed a preference for their L1 phoneme categorization (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992). In adults, BL listeners' central auditory systems are optimized (i.e., one "becomes neurally committed to a particular network structure for analyzing language;" Iverson et al., 2003, p. B55) such that acoustic signals that are characteristic of their L1 are more easily perceived than that characteristic of their L2. A number of anatomical and physiological studies have provided further evidence for the neural plasticity of the central auditory system with linguistic experience (e.g., Golestani, Molko, Dehaene, LeBihan, & Pallier, 2007; Näätänen, 2001; Näätänen et al., 1997; Poulsen, Picton, & Paus, 2007; Tremblay, Kraus, Carrell, & McGee, 1997; Winkler et al., 1999).

In investigating the effect of linguistic experience on speech perception, researchers have compared native Mandarin speakers with native English speakers (see below). Those who speak Mandarin have a unique linguistic experience relative to English speakers. Unlike English, Mandarin is a tonal language in which different pitch contours, principally carried by the vocalic part of the syllable, convey different lexical meanings (Li & Thompson, 1987). There are four tones (i.e., fundamental frequency contours) in Mandarin that can convey four different meanings. For example, the syllable /ma/ pronounced with either of the high level, high rising, low falling, or high falling tones can mean "mother," "hemp," "horse," or "to scold," respectively. Kuhl (2000) contents that "language experience changes one's discriminative abilities and listening preferences [and] it results in a 'mapping' that alters perception" (p. 11853). Hence, the linguistic experience of Mandarin speaking Chinese adults is believed to incline them to have better perception of auditory stimuli whose spectral and/or temporal properties resemble their speech. Specifically, because of their experience with their tonal language, Mandarin speakers are predisposed to perceive stimuli with tonal characteristics. Simply put, the language experience of native Mandarin speakers enhances processing of linguistically relevant tonal features in both temporal and spectral domains of acoustic input better than speakers of non-tonal languages. Conversely, listeners with different language backgrounds (e.g., English) typically show similar responses as Mandarin speakers to auditory stimuli whose spectral and/or temporal properties do not resemble tonal speech. This has been demonstrated in numerous studies outlined below with behavioral, psychoacoustic and electrophysiological measures.

Klein, Zatorre, Milner, and Zhao (2001), for example, compared native Mandarin and native English speakers' performance in tone discrimination with monosyllabic Mandarin words. Their behavioral data revealed that the Mandarin speakers responded with more accuracy, and their positron emission tomography data indicated that the Mandarin speakers showed more activation in the left hemisphere. Bent, Bradlow, and Wright (2006) demonstrated that native Mandarin speakers outperformed native English speakers in identifying tonal information in speech signals, whereas the two groups showed similar performance in non-speech pitch discrimination tasks. Interestingly, the authors found that the two groups showed differences in non-speech pitch contour identification tasks (e.g., native Mandarin speakers made more mistakes in identifying flat and falling pitch contours). Using two-alternative-forced-choice tasks, Luo, Boemio, Gordon, and Poeppel (2007) reported that native Mandarin speakers and native English speakers showed similar performance in discriminating frequency-modulated tone sweeps. However, comparing with their data from native English speakers, native Chinese speakers were better in detecting the directions of the tone sweeps. Gandour and colleagues used various methodologies, including mismatch negativity (Chandrasekaran, Gandour, & Krishnan, 2007; Chandrasekaran, Krishnan, & Gandour, 2007a, 2007b, 2009a, 2009b), functional magnetic resonance imaging (Gandour et al., 2003), brainstem frequency following response (Krishnan & Gandour, 2009; Krishnan, Gandour, Bidelman, & Swaminathan, 2009; Krishnan, Swaminathan, & Gandour, 2009; Krishnan, Xu, Gandour, & Cariani, 2004, 2005; Swaminathan, Krishnan, & Gandour, 2008; Swaminathan, Krishnan, Gandour, & Xu, 2008; Xu, Krishnan, & Gandour, 2006), and behavioral studies (Xu, Gandour, & Francis, 2006) to examine the effect of linguistic experience on Mandarin speakers' speech perception. Their findings converge on the notions that native Mandarin listeners generally are more sensitive to pitch contours than native English listeners and this difference is reflected on both cortical and subcortical levels.

The current study investigated Mandarin-English BLs' and American English MLs' word recognition in quiet and noise utilizing a paradigm developed by Stuart and colleagues (Elangovan & Stuart, 2005; Scott, Green, & Stuart, 2001; Stuart, 2004, 2005, 2008; Stuart & Carpenter, 1999; Stuart, Givens, Walker, & Elangovan, 2006; Stuart & Phillips, 1996, 1997, 1998; Stuart, Phillips, & Green, 1995). This paradigm requires listeners to identify words presented in backgrounds of continuous and interrupted noises as a function of signal-to-noise ratio (S/N). A perceptual advantage is generally evidenced with listeners in the interrupted noise. That is, listeners demonstrate superior speech perception at equivalent S/Ns in the interrupted noise relative to continuous noise (i.e., a release from masking [RFM]). This advantage has been attributed to a listener's ability to resolve speech fragments in the silent gaps between noise bursts. Since the long-term average spectra of the two noises are the same and differ only in their temporal continuity, any RFM evidenced is a demonstration of auditory temporal resolution. One can assess auditory temporal resolution capacity among groups of listeners by examining overall performance in the interrupted noise and also by examining the amount of RFM in the interrupted noise relative to the continuous noise. In his seminal study investigating speech intelligibility in interrupted noise, Miller (1947) attributed the mechanism for this perceptual advantage to the fact that "the recovery of the ear is rapid enough, and our ability to integrate fragments of speech is great enough, that any periodic interruption of masking sounds lowers its masking effectiveness" (p. 122). It has also been suggested that listeners get "glimpses" (Miller & Licklider, 1950) or "looks" (Dirks, Wilson, & Bower, 1969) or utilize "dip listening" (Füllgrabe, Berthommier, & Lorenzi, 2006) between the gaps of noise such that information is patched together in order to identify the speech stimuli. Two phenomena responsible for the masking effect on speech intelligibility observed in interrupted noise with monosyllabic stimuli were first posited by Dirks and colleagues (Dirks & Bower, 1970; Dirks et al., 1969): Simultaneous masking occurs during noise bursts and temporal masking (i.e., forward and backward masking) during the interburst intervals. Subsequent researchers have demonstrated that both forward and backward masking influence perception of stimuli in silent gaps bound by continuous noise (Elliot, 1969; Fastl, 1976, 1977, 1979; Patterson, 1971; Pollack, 1964; Robinson & Pollack, 1973; Wilson & Carhart, 1971).

To the best of our knowledge, this was the first study that employed a non-stationary energetic masker (i.e., interrupted noise) to evaluate BL listeners' L2 word recognition. Previous researchers have employed speech competitors that are stationary energetic maskers (e.g., continuous noise; Bradlow & Bent, 2002; Cooke et al., 2008; Gat & Keith, 1978; Kang, 1998; Meador et al., 2000; Nabelek & Donahue, 1984; Rogers et al., 2006; Shimizu et al., 2002; van Wijngaarden, Steeneken, & Houtgast, 2002; von Hapsburg et al., 2004; Weiss & Dempsey, 2008) or non-stationary informational maskers (e.g., competing speech or multitalker babble; Crandell & Smaldino, 1996; Cutler et al., 2004; Garcia Lecumberri & Cooke, 2006; Lew & Jerger, 1991; Lopez, Martin, & Thibodeau, 1997; Mayo et al., 1997; Nelson, Kohnert, Sabur, & Shaw, 2005; Takata & Nabelek, 1990; von Hapsburg and Bahng, 2006). Consequently, this paradigm was well suited to examine two areas of interest. The first concerned the effect of different speech competitors on BL listeners with non-native speech stimuli. The second area of interest concerned the effect of linguistic exposure and speech stimuli on listeners' temporal resolution ability (i.e., RFM). A number of hypotheses were formulated. In accordance with previous studies, it was hypothesized that

(1) performance in the continuous noise would be poorer than in the interrupted noise,

(2) performance would deteriorate with decreasing S/N,

(3) BLs would demonstrate more difficulty in perceiving L2 in noise compared to MLs,

(4) BLs would show similar performance in L2 perception as that of MLs in quiet,

(5) the RFM would be the same for the BLs across speech stimuli and that there would be no difference between MLs and BLs.

The final hypothesis was generated from the notion that the underlying basic temporal resolving abilities should be the same across these groups of listeners and that their language experiences should not predispose an advantage for one group over the other with this temporal resolution acuity paradigm. That is, while the BLs should have poorer perception of L2 in both noises compared to the MLs, the perceptual advantage achieved in the interrupted noise (i.e., RFM) should be the same as it can be attributed to basic underlying temporal acuity ability in all normal listeners.

METHOD

Participants

The BL group included 12 females (M = 25.7 years, range = 24 – 30) who were born in People's Republic of China. They were all East Carolina University graduate student[1] volunteers who responded to announcements soliciting participation. The BL participants completed a questionnaire that probed their linguistic profile (Grosjean, 1997; von Hapsburg & Pena, 2002). The questionnaire surveyed dimensions of language status, history, and competency of L1 and L2. Their L1 was Mandarin. They started to acquire English as their L2 at school at an average age of 11.8 years (range = 10 – 13). Therefore, they were considered as late elective BLs (von Hapsberg & Pena, 2002). They reported coming to the United States for graduate study and were considered still in the process of acquiring L2. Self-reported ratings of English proficiency were assessed with a five-point Likert scale (with 1 being poor and 5 excellent). Mean self-reported proficiencies were 3.3 (range = 3 – 4) for speaking, 3.7 (range = 3 – 5) for comprehension, and 3.5 (range = 3 – 5) for reading/writing. Self-reported ratings of speaking, comprehension, and reading/writing proficiency of Mandarin were excellent. Ten of 12 BL participants reported never speaking English at home. Eleven of 12 BL participants reported speaking English everyday at social occasions and everyday in professional situations. In contrast, 11 of 12 BL participants reported speaking Mandarin everyday at home. Eight of 12 BL participants reported speaking Mandarin everyday at social occasions. All 12 BL participants reported never speaking Mandarin in professional situations. When speaking with friends, six spoke mainly Mandarin, and six used both Mandarin and English. When speaking with coworkers, 11 of 12 BL participants used mainly English, and one used both languages. When speaking at home, 11 of 12 BL participants used mainly Mandarin and one used mainly English. When speaking at work, 11 of 12 BL participants used mainly English and one used both languages. While reading/writing for pleasure, 8 of 12 BL participants used both languages, and four used mainly Mandarin. While reading/writing for school, all used mainly English. While watching television, six of 12 BL participants viewed mainly English, five viewed both languages, and one viewed mainly Mandarin.

The ML group included 12 females (*M* = 20.5 years, range = 20 – 23) who spoke American English as their primary language. They were recruited from an undergraduate class in the Department of Communication Sciences and Disorders, East Carolina University, and received extra credit for their participation. ML participants also completed the same questionnaire that probed their linguistic profile. All of them reported having excellent English proficiency and used English as their primary language in all instances of daily living.

All participants presented with normal hearing sensitivity as defined by pure-tone thresholds of $\leq$ 25 dB HL (American National Standards Institute, 1996) at octave frequencies from 250 to 8000 Hz. Middle ear function was normal as defined by culturally appropriate normative data (Roup, Wiley, Safady, & Stoppenbach, 1998; Wan & Wong, 2002). Participants reported a negative history of speech, language, learning, and cognitive disorders.

Stimuli and Apparatus

The stimuli were speech test materials and custom competing background noise. The English test materials included Lists 1-4 of the Northwestern University Auditory Test No. 6 (female voice; Tillman & Carhart, 1966) released by the U.S. Department of Veteran Affairs (1991). Each list consisted of 50 monosyllabic words in consonant-vowel-consonant form. The competing stimuli were continuous or interrupted noises described in detail elsewhere (Stuart, 2004; Stuart & Philips, 1996, 1998). Briefly, these noises had an identical power spectrum and differed only in their temporal structures. The continuous noise was a broadband white noise with a flat spectrum within 2 dB from 100 to 8,000 Hz. The interrupted noise was made from the continuous noise wave by applying a random rectangular on/off envelope with a duty cycle of 0.50. It was characterized with silent gaps between noise bursts; both the gaps and noise bursts varied randomly from 5 to 95 ms. Randomized gating of the noise eliminates any pitch precept that may possibly arise from periodic modulation of the masker which could be utilized as a cue to segregate signal and noise by the listener (Stuart & Phillips, 1996, Stuart, 2004).

Participants were tested in a double-wall sound-treated audiometric suite meeting specifications for permissible ambient noise (American National Standards Institute, 1999). The audio signals were delivered from two compact disc players (Philips Model CDR 765 K02 and JVC Model XL-FZ258BK) to a clinical audiometer (Grason Stadler GSI 61 Model 1761-9780XXE) and presented monaurally to each participant's right ear through an insert earphone (Etymotic Research Model ER-3A).

Procedure

The University and Medical Center Institutional Review Board at East Carolina University approved all experimental procedures, including recruitment and acquisition of informed consent prior to data collection. All participants provided voluntary informed consent prior to data collection. The speech stimuli were presented to the participants at 30 dB sensation level relative to their three-frequency pure-tone average (i.e., 500, 1000, and 2000 Hz). The mean presentation levels were 37.1 dB HL (*SD* = 4.5) and 39.2 dB HL (*SD* = 2.3) for the BL group and ML group, respectively. These presentation levels were not statistically different, $t\ (22) = 1.35$, $p = 0.19$. Participants were first tested in quiet, and then in continuous and interrupted noise at three S/Ns (i.e., 10, 0, and -10 dB). The presentation order of the noise conditions was counterbalanced using a digram-balanced Latin-Square design (Wagenaar, 1969). Participants were instructed to repeat the words presented to them and to guess if necessary. The first author, fluent in both English and Mandarin, scored participants' responses. All participants were tested in one session typically lasting one hour. Adequate rest periods were provided between tasks and whenever requested.

RESULTS

Participants' performance was scored as total word percent correct. The mean word recognition scores were 95.8% (*SD* = 3.0) and 89.0 % (*SD* = 3.5) for the ML group and BL group, respectively. Prior to inferential analyses, the data were transformed into the rationalized arcsine units (Studebaker, 1985). An independent *t*-test revealed that ML participants performed significantly better than the BL participants, $t\ (22) = -4.98$, $p < 0.001$, $\eta^2 = .53$.

Figure 1 illustrates word recognition performance as a function of group, noise, and S/N. A three-factor mixed analysis of variance (ANOVA) was employed to examine word recognition performance as a function of group, noise, and S/N. The summary of that analysis is presented in Table 1. As shown in Table 1, all main effects and the interaction of noise × S/N were significant ($p < 0.001$). In general, the ML group performed better than BL group; all participants performed better in interrupted noise than continuous noise; and all participants' performance decreased with decreased S/N. To explore the source of the significant noise × S/N interaction a number of post hoc analyses were performed. Two orthogonal single-df comparisons were undertaken to examine the effect of S/N in continuous noise. Two orthogonal single-df comparisons were also undertaken to examine the effect of S/N in interrupted noise. For both noises, significant differences were found between scores at all three S/N ($p < 0.001$). Three paired-samples *t*-tests were utilized to examine differences between performances in continuous and interrupted noises at each S/N. There was no significant differences in word recognition performance at 10 dB and 0 dB S/N ($p > 0.05$). At -10 dB S/N performance was significantly better in the interrupted noise ($p < 0.001$).

RFM was calculated by subtracting word recognition percent correct in continuous noise from interrupted

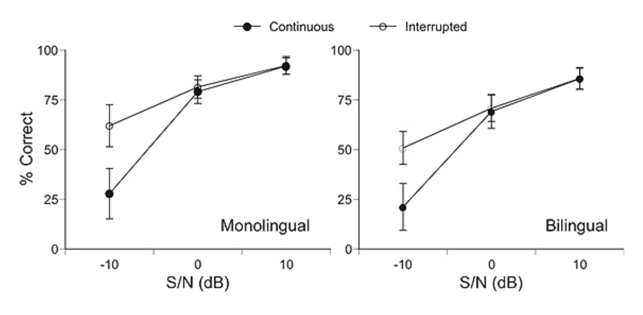

Figure 1.
Mean percent-correct word recognition as a function of group (i.e., monolingual and bilingual), noise (i.e., continuous and interrupted), and S/N. Error bars represent plus/minus one standard deviation of the mean.

noise at -10 dB S/N for each group (Stuart et al., 2006). Mean difference scores were 34.2% (*SD* = 11.1) and 29.7 % (*SD* = 9.8) for the ML group and BL group, respectively. An independent t-test revealed no significant differences between ML and BL group mean difference scores, $t\,(22) = 0.61$, $p = 0.55$, $\eta^2 = .017$.

Table 1

Summary of A Three-Factor Mixed Analysis of Variance Investigating Differences in Word Recognition Performance As A Function of Group, Noise, And S/N

Source	*df*	F	*p*	η^2
Group	1	14.93	0.001 *	0.40
Noise	1	113.53	< 0.001 *	0.84
S/N	2	540.23	< 0.001 *	0.96
Noise × group	1	0.48	0.50	0.02
S/N × group	2	0.21	0.81	0.01
Noise × S/N	2	110.21	< 0.001 *	0.83
Noise × group × S/N	2	0.12	0.89	0.01

Note. Effect size is indexed by η^2. Cohen (1988) classifies small, medium, and large effect size values as 0.10, 0.25, and 0.40, respectively. * Significant at $p < 0.05$.

DISCUSSION

Performance in Quiet

Contrary to our hypothesis, BLs in this study had significantly poorer word recognition for L2 stimulus relative to the MLs. While the majority of studies (Gat & Keith, 1978; Nabelek &. Donahue, 1984; Takata & Nabelek, 1990; Crandell & Smaldino, 1996; Mayo et al., 1997; Shimizu et al., 2002; Rogers et al., 2006) have found that BLs display native-like speech recognition like MLs, some have found the same difference as reported herein (Garcia Lecumberri & Cooke, 2006; Cooke et al., 2008). The relative differences in these studies may be attributed to differences in speech stimuli employed with the BL listeners. Average performance for adult ML English speakers with the NU-6 monosyllabic word materials is typically below 95% at presentation levels similar to that found in this study (Beattie, Edgerton, & Svihovec, 1977; Wilson, Coley, Haenel, & Browning, 1976; Wilson, Zizz, Shanks, & Causey, 1990; Stuart, Green, Phillips, & Stenstrom, 1994). The group difference in word recognition scores found in this study may simply be related to sampling error.

Performance in Noise

As hypothesized, performance improved with increasing S/N and was superior in interrupted noise relative to continuous noise at the poorest S/N. This is consistent with previous applications of this paradigm (Elangovan & Stuart, 2005; Scott et al., 2001; Stuart, 2005, 2008; Stuart & Carpenter, 1999; Stuart & Phillips, 1996, 1997, 1998; Stuart et al., 1995, 2006). As expected, the BLs perceived L2 speech stimulus poorer than MLs with both stationary and non-stationary energetic maskers. This is in agreement with previous research where poorer speech perception of L2 stimuli by BLs was observed (Bergman, 1980; Bradlow & Bent, 2002; Cooke et al., 2008; Cutler et al., 2004; Garcia Lecumberri & Cooke, 2006; Gat & Keith, 1978; Kang, 1998; Mayo et al., 1997; Nabelek & Donahue, 1984; Rogers et al., 2006; Shimizu et al., 2002; Takata, & Nabelek, 1990; Van Engen & Bradlow, 2007). This is the first demonstration of BLs' performance in a strictly non-stationary energetic masker. Some of the deficit displayed in noise can be attributed to the NU-6 stimuli as the BLs displayed a performance detriment in quiet and would therefore be expected to display at least an equivalent detriment in noise.

The differences, however, between the ML and BL participants did not increase as the S/N became less favorable, which is consistent with other researchers (Bradlow & Bent, 2002; Rogers et al., 2006). These findings appear equivocal, as others have observed that the perceptual difference between BLs and MLs becomes more pronounced when listening conditions become more degraded (Cooke et al., 2008; Crandell & Smaldino, 1996). Often listeners' performances are compared in energetic noise (i.e., white noise) to that in informational noise (i.e., multi-talker babble) and some have suggested that the native advantage in speech perception under noise may exist in both energetic and informational maskers. However, the finding of this study that the noise, group, and S/N interactions were not statistically significant (see Table 1) lead one to suggest that both stationary and non-stationary energetic maskers may not disproportionately affect native and non-native listeners' speech perception under noise. Therefore, the role of energetic and informational maskers in non-native perception (e.g., which masker contributes more to the native advantage, or non-native disadvantage) remains to be explored in speakers of different languages, between various energetic maskers, and with early and late BLs. It is also noteworthy that the results may be dependent on the stimuli used in this experiment. Previously, Cutler et al. (2004) found that phonemic identification does not contribute to the disproportionate native advantage in general speech perception under noise; that is, although non-natives performed poorer in phoneme identification under noise, the gap between native and non-native speakers did not widen with increased noise level. Therefore, it is possible that the disproportionate native advantage in speech recognition is not easy to be distinguished at phoneme and word levels, but may become evident when other speech stimuli and maskers are employed.

Temporal Resolution - Release from Masking

Another aim of the study was to examine the impact of linguistic exposure on listeners' temporal resolution ability as assessed with word recognition in noise. As noted above, temporal resolution with this paradigm may be examined with overall performance in the interrupted noise or indexed by RFM, the relative advantage of speech perception in interrupted noise compared to continuous noise at same -10 dB S/N. The advantage or RFM that listeners experience in interrupted noise has been hypothesized to be due to the capacity to resolve speech fragments in the silent gaps between noise bursts. With respect to overall performance in the interrupted noise, the BL listeners were poorer than the ML listeners for the same stimuli (i.e., L2). We do not, however, interpret these differences as evidence for a deficit in temporal resolution experienced with L2 stimuli per se. We ascribe the difference between the two groups to poorer processing efficiency for L2 stimuli by the BL participants. Processing efficiency refers to factors besides temporal and spectral resolution that influence one's capacity to perceive acoustic signals in noise (Hartley, Hill, & Moore, 2003; Hartley & Moore, 2002; Stuart, 2008). In other words, as a consequence of poor processing efficiency BL listeners need a higher S/N for L2 stimuli than MLs to perceive at an equivalent level of word recognition. Central to that argument is the fact that no differences were found with RFM between the ML and BL groups. That is, temporal resolution was the same between the English and Chinese participants. It can be inferred from the results that the temporal resolution ability, as indexed with a measure of RFM with this word recognition in noise paradigm, is independent of linguistic exposure (as examined between BLs and MLs with English).

A similar pattern of performance was recently observed with the same cohort of participants with sentence recognition materials (Stuart, Zhang, & Swink, 2010). Reception thresholds for sentences were determined with the same competing continuous and interrupted noises. The sentence stimuli employed consisted of the *Hearing in Noise Test* and the *Mandarin Hearing in Noise Test*. The measurement properties and test characteristics of both tests are equivalent (Wong, Liu, & Han, 2008; Wong, Soli, Liu, Han, & Huang, 2007). RFM (i.e., the difference of reception thresholds for sentences S/N in interrupted and continuous noise) was examined between and within groups. There was no significant difference for the BLs' RFM with L1 versus L2 sentence materials. The ML group had significantly greater RFM for the English stimuli compared to the BLs. Stuart et al. did not interpret the latter finding as a reflection of better temporal acuity in the ML English participants. They attributed the difference to a differential masking effect on the two sentence stimuli. That is, they evidenced no significant differences in reception threshold S/Ns between groups in the interrupted noise. The ML English participants, however, had significantly higher reception threshold S/Ns in continuous noise. The lower reception threshold for sentence S/N found with the *Mandarin Hearing in Noise Test* in continuous noise was attributed above to differences in the original Mandarin and English stimuli (Wong et al., 2007). This latter difference contributed to the group difference in the RFM.

If one views the ability to resolve auditory fragments in the silent gaps between the bursts of noise as elementary temporal auditory acuity ability then the findings of equivalent RFM are understandable. First, it is difficult to posit any reason for a language/experience dependent advantage for word recognition in interrupted noise for either the English or Mandarin speaking Chinese participants. It has been demonstrated repeatedly that Mandarin speakers have better pitch representation than English speaking listeners with both speech and non-speech context evidenced in both auditory evoked responses (Chandrasekaran et al., 2007a, 2007b; Krishnan & Gandour, 2009; Krishnan, Gandour, et al. 2009; Krishnan et al., 2004, 2005, 2009; Swaminathan, Krishnan, & Gandour, 2008; Swaminathan, Krishnan, Gandour, & Xu, 2008; Xu, Krishnan, & Gandour, 2006) and psychoacoustic measures (Bent et al., 2006; Francis & Ciocca, 2003; Lou et al., 2007; Xu, Gandour, & Francis, 2006). These differences have been attributed to language experience effects (i.e., repeated exposure in tonal language to pitch contour variations for lexical distinctions). The gating of the interrupted noise was random thereby eliminating any pitch percept that may possibly arise from periodic modulation of the noise that may be used as a cue to segregate signal and noise by the listener (Stuart, 2004; Stuart & Phillips, 1998). Eliminating any possible pitch percept would negate an advantage for the Mandarin speaking listeners.

CONCLUSIONS

Word recognition was examined in quiet and in two energetic noise maskers with identical power spectrums and different temporal continuity, as a function of S/N with Mandarin-English BLs and American English MLs. The first line on inquiry involved examining the effect of the different stationary (i.e., continuous noise) and non-stationary (i.e., interrupted noise) speech competitors on ML and BL listeners. The second line of inquiry involved examining the effect of linguistic exposure and speech stimuli on listeners' temporal resolution ability. This was the first study to evaluate BL listeners' L2 speech perception against a non-stationary speech competitor. As expected, performance for both groups was poorer in the continuous noise and deteriorated with decreasing S/N. At the poorest S/N, participants demonstrated superior performance in the interrupted noise compared to continuous noise (i.e., a RFM). BLs perceived L2 speech stimuli poorer than MLs with both stationary and non-stationary energetic maskers. The differences between the two groups, however, did not increase as the S/N became less favorable. Poorer processing efficiency for L2 stimuli was attributed for the inferior performance of the BL versus ML participants. Most important was the fact that there were no differences in the RFM between the ML and BL groups. It was inferred that the temporal resolution ability, as indexed with a measure of RFM, is independent of linguistic exposure of listeners. This is consistent with the view that this word recognition in noise paradigm exposes basic temporal resolution ability and is not language or experience-dependent.

REFERENCES

American National Standards Institute 1996. *Specification for audiometers.* (ANSI S3.6-1996). New York: ANSI.

American National Standards Institute (1999). *Permissible ambient noise levels for audiometric test rooms.* (ANSI S3.1-1999). New York: ANSI.

Beattie, R. C., Edgerton, B. J., & Svihovec, D. V. (1977). A comparison of the Auditec of St. Louis cassette recordings of NU-6 and CID W-22 on a normal-hearing population. Journal of Speech and Hearing Disorders, 42, 60-64.

Bent, T., Bradlow, A. R., & Wright, B. A. (2006). The influence of linguistic experience on the cognitive processing of pitch in speech and nonspeech sounds. *Journal of Experimental Psychology: Human Perception and Performance, 32,* 97-103.

Bergman, M. (1980). *Aging and the perception of speech.* Baltimore, MD: University Park Press.

Bradlow, A. R., & Bent, T. (2002). The clear speech effect for non-native listeners. *Journal of the Acoustical Society of America, 112*, 272-284.

Chandrasekaran, B., Gandour, J. T., & Krishnan, A. (2007). Neuroplasticity in the processing of pitch dimensions: a multidimensional scaling analysis of the mismatch negativity. *Restorative Neurology and Neuroscience, 25*, 195-210.

Chandrasekaran, B., Krishnan, A., Gandour, J. T. (2007a). Mismatch negativity to pitch contours is influenced by language experience. *Brain Research, 1128*, 148-156.

Chandrasekaran, B., Krishnan, A., Gandour, J. T. (2007b). Experience-dependent neural plasticity is sensitive to shape of pitch contours. *Neuroreport, 18,* 1963-1967.

Chandrasekaran, B., Krishnan, A., & Gandour, J. T. (2009a). Relative influence of musical and linguistic experience on early cortical processing of pitch contours. *Brain and Language, 108*, 1-9.

Chandrasekaran, B., Krishnan, A., & Gandour, J. T. (2009b). Sensory processing of linguistic pitch as reflected by the mismatch negativity. *Ear and Hearing, 30*, 552-558.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Cooke, M., Garcia Lecumberri, M. L., & Barker, J. (2008). The foreign language cocktail party problem: Energetic and informational masking effects in non-native speech perception. *Journal of the Acoustical Society of America, 123*, 414-427.

Crandell, C., & Smaldino, J. J. (1996). Speech perception in noise by children for whom English is a second language. *American Journal of Audiology, 5*, 47-51.

Cutler, A., Weber, A., Smits, R., & Cooper, N. (2004). Patterns of English phoneme confusions by native and non-native listeners. *Journal of the Acoustical Society of America, 116,* 3668-3678.

Dirks, D. D., & Bower, D. R. (1970). Effect of forward and backward masking on speech intelligibility. *Journal of the Acoustical Society of America, 47,* 1003-1008.

Dirks, D. D., Wilson, R. H., & Bower, D. R. (1969). Effect of pulsed masking on selected speech materials. *Journal of the Acoustical Society of America, 46,* 898-906.

Elangovan, S., & Stuart, A. (2005). Interactive effects of high-pass filtering and masking noise on word recognition. *The Annals of Otology, Rhinology and Laryngology, 114*, 867-879.

Elliot, L. L. (1969). Masking of tones before, during, and after brief silent periods. *Journal of the Acoustical Society of America, 45*, 1277-79.

Fastl, H. (1976). Temporal masking effects: I. Broad band noise masker. *Acoustica, 35*, 287-302

Fastl, H. (1977). Temporal masking effects: II. Critical band masker. *Acoustica, 36*, 317-331.

Fastl, H. (1979). Temporal masking effects: III. Pure tone masker. *Acoustica, 43*, 282-294.

Füllgrabe, C., Berthommier, F., & Lorenzi, C. (2006). Masking release for consonant features in temporally fluctuating background noise. *Hearing Research, 211*, 74-84.

Francis, A. L., & Ciocca, V. (2003). Stimulus presentation order and the perception of lexical tones in Cantonese. *Journal of the Acoustical Society of America, 114*, 1611-1621.

Gandour, J., Dzemidzic, M., Wong, D., Lowe, M., Tong, Y., Hsieh, L., Satthamnuwong N., & Lurito J. (2003). Temporal integration of speech prosody is shaped by language experience: An fMRI study. *Brain and Language, 84*, 318-336.

Garcia Lecumberri, M. L., & Cooke, M. (2006). Effect of masker type on native and non-native consonant perception in noise. *Journal of the Acoustical Society of America, 119*, 2445-2454.

Gat, I. B., & Keith, R. W. (1978). An effect of linguistic experience: Auditory word discrimination by native and non-native speakers of English. *Audiology, 17*, 339-345.

Golestani, N., Molko, N., Dehaene, S., LeBihan, D., & Pallier, C. (2007). Brain structure predicts the learning of foreign speech sounds. *Cerebral Cortex, 17*, 575-582.

Grosjean, F. (1997). Processing mixed language: Issues, findings, and models. In A.M.B. de Grout & J.F. Kroll (Eds.), *Tutorials in bilingualism: Psycholinguistic perspectives* (pp. 225-251). Mahwah, NJ: Lawrence Erlbaum Associates.

Hartley, D. E., Hill, P. R., & Moore, D. R. (2003). The auditory basis of language impairments: temporal processing versus processing efficiency hypotheses. *International Journal of Pediatric Otorhinolaryngology, 67* (Suppl. 1), S137-S142.

Hartley, D. E., & Moore, D. R. (2002). Auditory processing efficiency deficits in children with developmental language impairments. *Journal of the Acoustical Society of America, 112*, 2962-2966.

Iverson, P., Kuhl, P. K., Akahane-Yamada, R., Diesch, E., Tohkura, Y., Kettermann, A., & Siebert, C. (2003). A perceptual interference account of acquisition difficulties for non-native phonemes. *Cognition, 87*, B47-B57.

Jia, G., Strange, W., Wu, Y., Collado, J., & Guan, Q. (2006). Perception and production of English vowels by Mandarin speakers: Age-related differences vary with amount of L2 exposure. *Journal of the Acoustical Society of America, 119*, 1118-1130.

Kang, J. (1998). Comparison of speech intelligibility between English and Chinese. *Journal of the Acoustical Society of America, 103*, 1213-1216.

Klein, D., Zatorre, R.J., Milner, B., & Zhao, V. (2001). A cross-linguistic

PET study of tone perception in Mandarin Chinese and English speakers. *NeuroImage, 13*, 646–653.

Krishnan, A., & Gandour, J. T. (2009). The role of the auditory brainstem in processing linguistically-relevant pitch patterns. *Brain and Language, 110*, 135-148.

Krishnan, A., Gandour, J. T., Bidelman, G. M., & Swaminathan, J. (2009). Experience-dependent neural representation of dynamic pitch in the brainstem. *Neuroreport, 20*, 408-413.

Krishnan, A., Swaminathan, J., & Gandour, J. T. (2009). Experience-dependent enhancement of linguistic pitch representation in the brainstem is not specific to a speech context. *Journal of Cognitive Neuroscience, 21*, 1092-1105.

Krishnan, A., Xu, Y., Gandour, J. T, Cariani, P.A. (2004). Human frequency-following response: representation of pitch contours in Chinese tones. *Hearing Research, 189*, 1-12.

Krishnan, A., Xu, Y., Gandour, J., & Cariani, P. (2005). Encoding of pitch in the human brainstem is sensitive to language experience. *Cognitive Brain Research, 25*, 161-168.

Kuhl, P. K. (2000). A new view of language acquisition. *Proceedings of the National Academy of Sciences of the United States of America, 97*, 11850-11857.

Kuhl, P. K., Williams, K. A., Lacerda, F., Stevens, K. N., & Lindblom, B. (1992). Linguistic experience alters phonetic perception in infants by 6 months of age. *Science, 255*, 606-608.

Levi, S. V., Winters, S. J., & Pisoni, D. B. (2007). Speaker-independent factors affecting the perception of foreign accent in a second language. *Journal of the Acoustical Society of America, 121*, 2327-2338.

Lew, H., & Jerger, J. (1991) Effect of linguistic interference on sentence identification. *Ear and Hearing, 12*, 365-367.

Li, C.N., & Thompson, S.A. (1987). Chinese. In B. Comrie (Ed.), *The world's major languages* (pp. 811-833). New York: Oxford University Press.

Lopez, S. M., Martin, F. N, Thibodeau, L. M. (1997) Performance of monolingual and bilingual speakers of English and Spanish on the Synthetic Sentence Identification Test. *Journal of the American Academy of Audiology, 6*, 33-38.

Luo, H., Boemio, A., Gordon, M., & Poeppel, D. (2007). The perception of FM sweeps by Chinese and English listeners. *Hearing Research, 224*, 75-83.

Mayo, L. H., Florentine, M., & Buus, S. (1997). Age of second-language acquisition and perception of speech in noise. *Journal of Speech and Hearing Research, 40*, 686-693.

Meador, D., Fledge, J. E., & Mackay I. R. A. (2000). Factors affecting the recognition of words in a second language. *Bilingualism: Language and Cognition, 3*, 55-67.

Miller, G. A. (1947). *The masking of speech. Psychological Bulletin, 44*, 105-129.

Miller, G. A., & Licklider, C. R. (1950). The intelligibility of interrupted speech. *Journal of the Acoustical Society of America, 22*, 167-173.

Näätänen, R. (2001). The perception of speech sounds by the human brain as reflected by the mismatch negativity (MMN) and its magnetic equivalent (MMNm). *Psychophysiology, 38*, 1-21.

Näätänen, R., Lehtokoski, A., Lines, M., Cheour, M., Huotilainen, M., Yvonne, A., et al. (1997). Language-specific phoneme representations revealed by electric and magnetic brain responses. *Nature, 385*, 432-434.

Nabelek, A. K., & Donahue, A. M. (1984). Perception of consonants in reverberation by native and non-native listeners. *Journal of the Acoustical Society of America, 75*, 632-634.

Nelson, P., Kohnert, K., Sabur, S., & Shaw, D. (2005). Classroom noise and children learning through a second language: double jeopardy? *Language, Speech, and Hearing Services in Schools, 36*, 219-229.

Patterson, J. H. (1971). Additivity of forward and backward masking as a function of signal level. *Journal of the Acoustical Society of America, 50*, 1123-1125.

Pisoni, D. B., Lively, S.E., & Logan, J. S. (1994). Perceptual learning of nonnative speech contrasts: implications for theories of speech perception. In J.C. Goodman & H.C. Nusbaum (Eds.), *The development of speech perception: the transition from speech sounds to spoken words* (pp. 121-166). Cambridge, MA: MIT Press.

Pollack, I. (1964). Interaction of forward and backward masking. *Journal of Auditory Research, 4*, 63-67.

Poulsen, C., Picton, T. W., & Paus, T. (2007). Age-Related Changes in Transient and Oscillatory Brain Responses to Auditory Stimulation in Healthy Adults 19-45 Years Old. *Cerebral Cortex, 17*, 1454-1467.

Robinson, C. E., & Pollack, I. (1973). Interaction between forward and backward masking: a measure of the integrating period of the auditory system. *Journal of the Acoustical Society of America, 53*, 1313-1316.

Rogers, C. L., Lister, J. J., Febo, D. M., Besing, J. M., & Abrams, H. B. (2006). Effects of bilingualism, noise, and reverberation on speech perception by listeners with normal hearing. *Applied Psycholinguistics, 27*, 465-485.

Roup, C. M., Wiley, T. L., Safady, S. H., & Stoppenbach, D. T. (1998). Tympanometric screening norms for adults. *American Journal of Audiology, 7*, 55-60.

Scott, T., Green, W. B., & Stuart, A. (2001). Interactive effects of low-pass filtering and masking noise on word recognition. *Journal of the American Academy of Audiology, 12*, 437-444.

Shimizu, T., Makishima, K., Yoshida, M., & Yamagishi, H. (2002). Effect of background noise on perception of English speech for Japanese listeners. *Auras, Nisus, Larynx, 29*, 121-125.

Stuart, A. (2004). An investigation of list equivalency of the Northwestern University Auditory Test No. 6 in interrupted broadband noise. *American Journal of Audiology, 13*, 23-28.

Stuart, A. (2005). Development of auditory temporal resolution in school-age children revealed by word recognition in continuous and interrupted noise. *Ear and Hearing, 26*, 78-88.

Stuart, A. (2008). Reception thresholds for sentences in quiet, continuous noise, and interrupted noise in school-age children. *Journal of the American Academy of Audiology, 19*, 135-146.

Stuart, A., & Carpenter, M. (1999). Unilateral auditory temporal resolution deficit: A case study. *Journal of Communication Disorders, 32*, 317-324.

Stuart, A., Givens, G. D., Walker, L. J., & Elangovan, S. (2006). Auditory temporal resolution in normal-hearing preschool children revealed by word recognition in continuous and interrupted noise. *Journal of the Acoustical Society of America, 119*, 1946-1949.

Stuart, A., Green, W. B., Phillips, D. P., & Stenstrom, R. (1994). List equivalency of the Northwestern University Auditory Test No. 6 in quiet and in continuous broad band noise. J*ournal of Speech-Language-Pathology and Audiology, 18*, 121-125.

Stuart, A., & Phillips, D. P. (1996). Word recognition in continuous and interrupted broadband noise by young normal-hearing, older normal-hearing, and presbyacusic listeners. *Ear and Hearing, 17*, 478-489.

Stuart, A., & Phillips, D. P. (1997). Word recognition in continuous noise, interrupted noise, and in quiet by normal-hearing listeners at two sensation levels. *Scandinavian Audiology, 26*, 112-116.

Stuart, A., & Phillips D. P. (1998). Deficits in auditory temporal resolution revealed by a comparison of word recognition under interrupted and continuous noise masking. *Seminars in Hearing, 19*, 333-344.

Stuart, A., Phillips, D. P., & Green, W. B. (1995). Word recognition performance in continuous and interrupted broad-band noise by normal-hearing and simulated hearing-impaired listeners. *American Journal of Otology, 16*, 658-663.

Stuart, A., Zhang, J., & Swink, S. (2010). Reception thresholds for sentences in quiet and noise for monolingual English and bilingual Mandarin-English listeners. *Journal of the American Academy of Audiology, 21*, 239-248.

Studebaker, G. (1985). A "rationalized" arcsine transform. *Journal of Speech and Hearing Research, 28*, 455-462.

Swaminathan, J., Krishnan, A., & Gandour, J. T. (2008). Pitch encoding in speech and nonspeech contexts in the human auditory brainstem. *Neuroreport, 19*, 1163-1167.

Swaminathan, J., Krishnan, A., Gandour, J. T., & Xu, Y. (2008). Applications of static and dynamic iterated rippled noise to evaluate pitch encoding in the human auditory brainstem. *IEEE Transactions on Bio-medical Engineering, 55*, 281-287.

Takata, Y., & Nabelek, A. K. (1990). English consonant recognition in noise and in reverberation by Japanese and American listeners. *Journal of the Acoustical Society of America, 88*, 663-666.

Tillman, T. W., & Carhart, R. (1966). *An expanded test for speech discrimination utilizing CNC monosyllabic words. Northwestern University Auditory Test No. 6* (Tech. Rep. No. SAM-TDR-66-55). Brooks Air Force Base, TX: USAF School of Aerospace Medicine.

Tong, Y., Francis, A. L., & Gandour, J. T. (2008). Processing dependencies between segmental and suprasegmental features in Mandarin Chinese. *Language and Cognitive Processes, 23*, 689-708.

Tremblay, K., Kraus, N., Carrell, T. D., & McGee, T. (1997). Central auditory system plasticity: Generalization to novel stimuli following listening training. *Journal of the Acoustical Society of America, 102*, 3762-3773.

Van Engen, K. J., & Bradlow, A. R. (2007). Sentence recognition in native-and foreign-language multi-talker background noise. *Journal of the Acoustical Society of America, 121*, 519-526.

van Wijngaarden, S. J., Steeneken, H. J. M., & Houtgast, T. (2002). Quantifying the intelligibility of speech in noise for non-native listeners. *Journal of the Acoustical Society of America, 111*, 1906-1916.

von Hapsburg, D., & Bahng, J. (2006). Acceptance of background noise levels in bilingual (Korean-English) listeners. *Journal of the American Academy of Audiology, 17*, 649-658.

von Hapsburg, D., & Pena, E. D. (2002). Understanding bilingualism and its impact on speech audiometry. *Journal of Speech and Hearing Research, 45*, 202-213.

Wagenaar, W. A. (1969). Note on the construction of digram-balanced Latin squares. *Psychological Bulletin, 72*, 384-386.

Wan, I. K. K., & Wong, L. L. N. (2002). Tympanometric norms for Chinese young adults. *Ear and Hearing, 23*, 416-421.

Weiss, D., & Dempsey, J. J. (2008). Performance of bilingual speakers on the English and Spanish versions of the Hearing in Noise Test (HINT). *Journal of the American Academy of Audiology, 19*, 5-17.

Wilson, R. H., & Carhart, R. (1971). Forward and backward masking: Interactions and additivity. *Journal of the Acoustical Society of America, 49*, 1254-1263.

Winkler, I., Kuala, T., Tiitinen, H., Silone, P., Alou, P., Lehtokoski, A., et al. (1999). Brain responses reveal the learning of foreign language phonemes. *Psychophysiology, 36*, 638-642.

Wong, L. L. N., Liu S., & Han, N. (2008). The Mainland Mandarin hearing in noise test. *International Journal of Audiology, 47*, 393-395.

Wong, L. L. N., Soli, S. D., Liu, S., Han, N., & Huang, M.W. (2007). Development of the Mandarin Hearing in Noise Test (MHINT). *Ear and Hearing, 28*, 70S-74S.

Xu, Y., Gandour, J. T., & Francis, A. L. (2006). Effects of language experience and stimulus complexity on the categorical perception of pitch direction. *Journal of the Acoustical Society of America, 120*, 1063-1074.

Xu, Y., Krishnan, A., & Gandour, J. T. (2006). Specificity of experience-dependent pitch representation in the brainstem. *Neuroreport, 17*, 1601-1605.

ENDNOTE

[1] A standardized test of English proficiency was not administered to the BL participants. We assumed a minimal level of English proficiency among these participants, as they were all graduate students at East Carolina University. For admission, the university requires students to meet a language exam requirement of a TOEFL® score of 20 on each section for a total minimum score of 80, 550 (paper based), or 213 (computer based), or IELTS™ score of 6.5.

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