UC Merced

Proceedings of the Annual Meeting of the Cognitive Science Society

Title

Attentional and Immediate Memory Capacity Limitations in the Acquisition of Non-Native Linguistic Contrasts

Permalink

https://escholarship.org/uc/item/81b1k7k1

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 36(36)

ISSN

1069-7977

Authors

Schoenherr, Jordan
Logan, John

Publication Date

2014

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

Attentional and Immediate Memory Capacity Limitations in the Acquisition of Non-Native Linguistic Contrasts

Jordan Schoenherr (psychophysics.lab@gmail.com)
John Logan (john.logan@carleton.ca)
Department of Psychology, Carleton University
1125 Colonel By Drive, Ottawa, ON K1S5B6 Canada

Abstract

The acquisition of a non-native phonetic distinction by second-language learners relies on basic sensory and perceptual processes. In the present study we examined whether central capacity limitations in attention and immediate memory affected both metalinguistic awareness of phonemic properties of stimuli and the ease with which listeners could perceptually reorganize native phonemic categories. Immediate memory was positively related to performance when listeners had to monitor their performance whereas attention was positively related to performance in identifying stimuli along the acoustic continuum.

Keywords: speech perception, category boundaries, confidence processing, second language acquisition

Introduction

In the 1970s and 1980s the framework of categorical perception (Liberman, Harris, Hoffman, & Griffith, 1957) was a major impetus to work examining nonnative speech perception in both adults (e.g., Pisoni, Aslin, Perey, & Hennessey, 1982) as well as its developmental antecedents (e.g., Aslin, Pisoni, Hennessey, & Perey, 1981). Although this framework was integrated into mainstream cognitive psychology via accounts of how auditory information could be transformed into a more durable phonetic code (e.g., Pisoni, 1973), comparatively few studies have considered the extent to which attention and immediate memory limitations affect this process. The present study examines these limitations in a speech perception task wherein listeners must learn to perceptually reorganize an acoustic continuum to accommodate a non-native speech sound.

Categorical Perception of Speech Sounds

Phonemic distinctions are evident early in development. Starting at the end of the first year (Werker, 1989) and continuing into adulthood (Hazan & Barrett, 2000), listeners become desensitized to differences between speech sounds within a specific range (we use "desensitized" here as a neutral term that does not necessarily imply a loss of sensory ability). As a result of the experience, adult listeners use a highly restricted set of acoustic cues to differentiate speech sounds (Jusczyk, 1992, 2000) similar to the way attention is allocated in categorization tasks more generally (e.g., Nosofsky, 1986). Although some researchers originally claimed that adult listeners can no longer detect within-category differences between speech sounds (e.g., Eimas, 1975), later studies suggested that the ability to perceive at least some non-native contrasts can be demonstrated in adulthood (e.g., Pisoni, Aslin, Perey, & Hennessy, 1982; Werker & Logan, 1984). In order to determine the extent to which the categorization of speech sounds is malleable, it is useful to consider the processes underlying categorization more generally.

Contributions of Immediate and Long-Term Memory

In a manner similar to studies of speech perception, categorization studies have examined how attention can be focused on a region of a perceptual continuum through feedback (Nosofsky, 1986), which can in turn transfer to other tasks, such as stimulus discrimination performance (Goldstone, 1994). In addition to attention, categorization models have also noted how limited immediate memory constrains categorization performance. For instance, Ashby, Alfonso-Reese, Turken, and Waldron (1998) suggests a two-process account wherein a fast, explicit hypothesis-testing system which relies on attention and immediate capacity retains a small number of stimulus dimensions (usually one) to categorize stimuli. This explicit system dominates response selection during early stages of training. The explicit categorization system is in competition with a slower, implicit procedural-learning system that can acquire multidimensional categorization structures. After extensive training, the procedural-learning system dominates response selection. Although a number of categorization models have been proposed to account for how categories are learned, few models of speech perception have incorporated these findings.

Pisoni and colleagues (e.g., Pisoni & Tash, 1974) provided an early account of speech perception that shares some features with categorization models. They proposed a two-process model of speech perception in the context of an ABX discrimination task. This model assumes that listeners can initially use the acoustic properties of the stimuli stored in immediate memory. If the sounds are identical or they are distal to one another on a perceptual continuum, response selection will occur rapidly using acoustic properties. When stimuli are more confusable due to being close together in psychological space and within the same category, a secondary processing stage using the phonemic properties stored in long-term memory is activated. If acoustic information is available to listeners (see Schoenherr & Logan, 2013), it remains unclear whether listeners represent this information explicitly or implicitly.

Supporting the possibility of metalinguistic awareness during speech perception, immediate memory has been shown to be a determinant of the acquisition of native (e.g., Gathercole et al., 1992) and non-native vocabulary (e.g., Papagno, Valentine, & Baddeley, 1991). Capacity limitations also affect speech perception according to some studies. Pisoni and Greers (2000) investigated children who received cochlear implants (CIs) and found immediate memory was related to subsequent improvements in speech perception. In conjunction with early studies that provided listeners with explicit instructions to attend to acoustic differences (Pisoni & Lazarus, 1974), these results suggest considerable involvement of an explicit learning system during perceptual reorganization. If correct, estimating the role and capacity of executive function becomes crucial. In the present study, we examine two aspects of executive function, attentional control and executive working memory capacity, to assess their impact on learning.

Alternative accounts have instead claimed that speech perception is largely an implicit process. For instance, Ellis (1992; 2002) has emphasized the substantial contributions of implicit learning to language perception and production. Frequency-based effects (e.g., Maye, Werker, & Gerken, 2002) are thought to underlie natural language acquisition (for reviews, see Ellis, 1994) and the development of artificial grammars (e.g., Reber, 1967). Additionally, using a factor analysis of a psychometric battery, Ellis (1994) provided evidence for both implicit and explicit processing in second-language acquisition. A recent study by Schoenherr and Logan (2013) further qualifies this pattern. They examined acquisition of a non-native linguistic contrast along the voice-onset time continuum. Using identification performance, typicality ratings, and subjective confidence reports, Schoenherr and Logan demonstrated that whereas acoustic properties affected performance in the identification task and typicality ratings, subjective awareness appeared to reflect native linguistic categories rather than acoustic properties or the novel category boundary that they were attempting to induce in the listeners.

Present Study

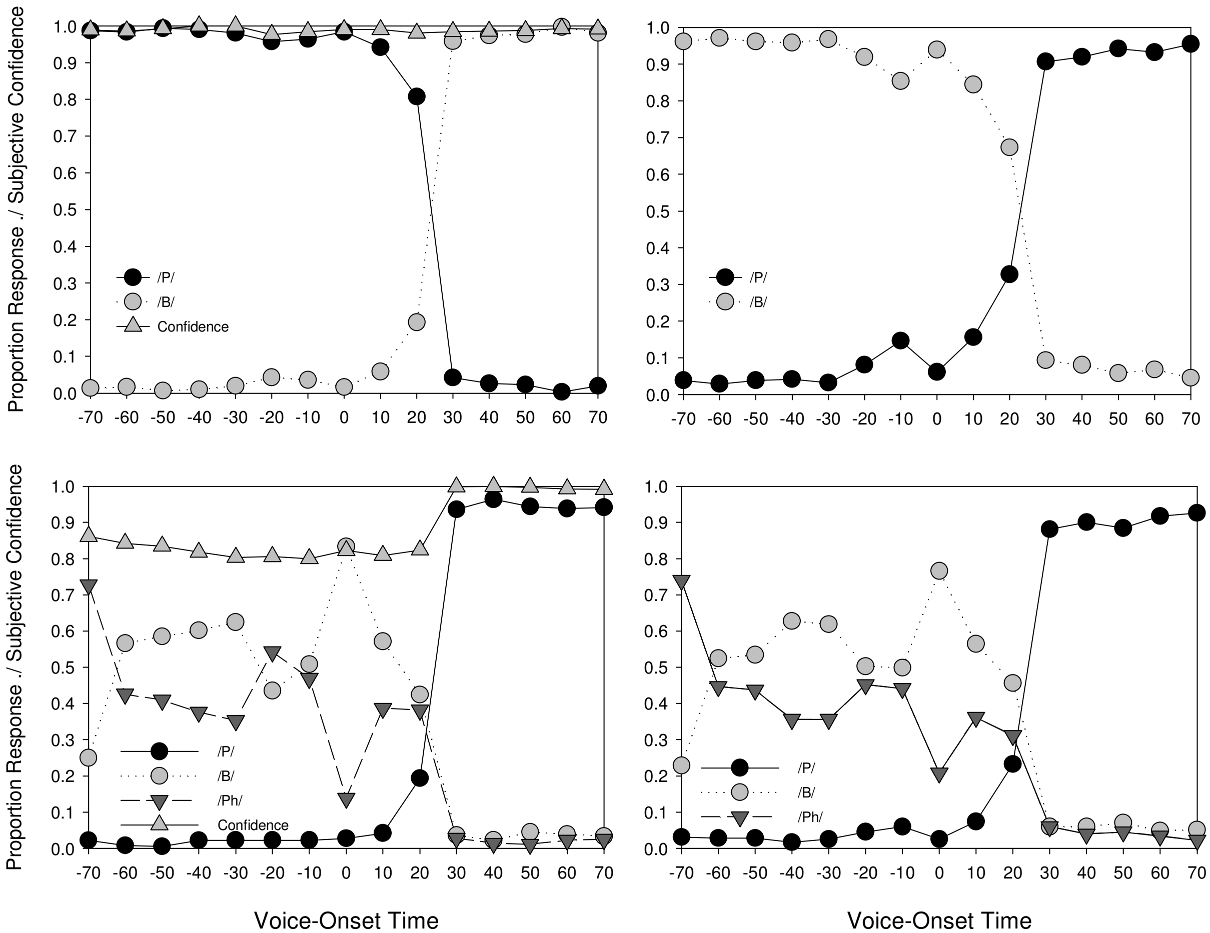
Ellis (1994) and Schoenherr and Logan (2013) demonstrated a need to assess both implicit and explicit sources of information in perception. In the present study we again adopt subjective confidence reports on a scale of 50% (guess) to 100% (certain) in the study of subjective awareness in speech perception (e.g., Schoenherr & Logan, 2013). We have previously argued that overconfidence (i.e., when mean confidence is greater than accuracy) is observed, it suggests subjective awareness of phonemes. In contrast, response selection (i.e., the response to the speech stimulus in a identification or discrimination task) appears to be dominated by implicit acoustic properties of speech sounds. This interpretation is consistent with a recent study by Schoenherr and Lacroix (2013) that obtained greater overconfidence bias for category structures thought have explicit representations relative to a category structure thought to have an implicit learning representation.

Divergent evidence for explicit and implicit representations of speech sounds can also be obtained using measures of immediate memory and attention. Models of immediate memory typically include an active executive function that maintains stimulus representations in the focus of attention (for a review, see Miyake & Shah, 1999). In addition to generative tests (Baddeley, 1996), Engle et al. (1999) developed a reading span task to examine executive function. In this task participants are presented with grammatical sentences that vary in terms of the realizability of their semantic content (e.g., "The young pencil kept his eyes closed until he was told to look."), responding either 'Yes' or 'No' based on whether the sentences were meaningful. Following each sentence, participants were then presented with a stimulus (e.g., the word "SPOT") that they would be asked to recall at the end of the task. Recall of these stimulus strings occurred after the presentation of 2 to 5 sentences.

Contemporary models of attention also suggest that attentional capacity is subject to a neuroanatomically-based functional division. Posner and colleagues (e.g., Posner & Dehaene, 1994) suggest a functional dissociation of neuroanatomical attention networks supporting alerting, orientation, and control. Fan et al. (2002) developed a task (the Attentional networks test, or ANT) that combined a visuospatial flanker task and a cued reaction time task, revealing three distinct reaction time patterns corresponding to three attention networks.

In the present experiment, we obtained responses to measures of attention and immediate memory and compared the results to identification performance and subjective confidence reports in a speech perception task. We interpreted evidence of overconfidence as suggestive of explicit phonemic representations of speech sounds. Additional evidence of explicit representations should also be observed in strong positive correlations with attentional measures of attentional control on the ANT and reading span. Implicit representations should be evidenced in identification performance, measures of orientation on the ANT, and immediate memory components that require less attentional control (ISPAN) relative to other measures (RSPAN).

Replicating earlier studies (e.g., Pisoni et al. 1982; Schoenherr & Logan, 2013) we used stimuli selected from the VOT continuum and required listeners to learn a non-native linguistic contrast from a portion of the continuum for which they should have little to no familiarity. Because stimuli from the /p^h-b/ portion of the VOT continuum have novel acoustic properties for listeners who do not use this category, these listeners should experience increased uncertainty if acoustic properties are being used to identify the stimuli whereas the participants should remain certain in their judgments of stimuli associated with the /p/ category that they are familiar with.



Method

Participants

Sixty-six Carleton University students participated in the study for course credit; all were native speakers of English or had extensive experience with English and reported normal hearing and no speech pathologies.

Materials

Identification Stimuli. Fifteen synthetic speech stimuli were obtained from the Haskins Laboratories website (HL, 2011; Lisker & Abramson, 1967). These stimuli varied along the VOT continuum from -70 to 70 ms VOT. As per the method used by Pisoni et al. (1982), listeners were presented with stimuli which corresponded to the voiceless unaspirated, voiced aspirated, and voiceless aspirated stops. The latter categories are present in English while the former is not. The sounds were originally recorded on reel-to-reel tape and later converted into AIFF format at Haskins Laboratories. Stimuli were pre-processed using a DC offset correction to eliminate clicks present in the AIFF versions and then converted into .WAV files using Audacity software.

Individual Differences Measures. Reading span (RSPAN) stimuli consisted of sentences that were adopted from Engle et al. (1999). Forty-two sentences were presented in sets of 2 to 5. Each set was followed by a randomly selected letter. A total of 10 stimulus sets were created for the letter span task, each consisting of eight random letters. Five sets were created to assess forward and backward span. Two variants of the task were used consisting of auditory (ASPAN) and visual stimuli (VSPAN).

The ANT was retrieved from https://sacklerinstitute.org/cornell/assays_and_tools/ant/jin.fan/. The program contained flanker stimuli consisting of a centrally presented arrow pointing in either a leftward or rightward direction. Conditions included congruent (→→→), incongruent (←→←), and no flanking stimuli (→). The target location could either be cued or left uncued (for a complete description of stimulus, conditions, and computation of ANT scores, see Fan et al., 2002). Listeners simply clicked a button corresponding to the direction of the arrow located in the middle of the array.

Procedure

Procedures were adapted from those used by Pisoni et al. (1982). Listeners initially received training in which they were presented with three stimuli each selected from the three critical regions along the VOT continuum (-70, 0, and 70 ms VOT, corresponding to the $/p^h/$, /b/, and /p/ categories). After presentation, they then indicated whether the speech sounds represented a $/p^h/$, /b/, or /p/ phoneme using the 'V', 'B', or 'N' keys, labelled as '_B', 'B', and 'P', respectively. After they had indicated their response, 'Correct' or 'Incorrect' was presented visually on the screen. Each stimulus was presented a total of 60 times during the training phase, for a total of 180 trials.

Following training, listeners again identified the full set of stimuli as a $/p^h/$, /b/, or /p/ using the keyboard but no feedback was provided. In the first block, after they completed each ID trial they also indicated their level of confidence in their response using the ‘E’ through ‘I’ keys, which were labeled to represent a 6-point scale with 50% representing a guess and 100% representing certainty. In the second block, confidence was not reported. Confidence and No confidence consisted of 150 trials each (15 stimuli × 10 repetitions). Block order was also counterbalanced.

Individual differences measures were presented prior to the primary task. They included the administration of the ANT, RSPAN, as well as the ASPAN and VSPAN tasks. Listeners were presented with the visual stimuli via a laptop computer. Auditory stimuli were presented over headphones at a comfortable listening level. Presentation of stimuli and collection of responses was controlled by PsychoPy software (Peirce, 2007). The experiment took place in a sound-attenuated booth and required approximately 120 mins to complete.

Results

An analysis of covariance (ANCOVA) was conducted on mean identification accuracy and mean subjective confidence with the ANT and immediate memory scores as covariates. Due to space limitations and correlations amongst measures, ANT and immediate memory subscores were combined into single variables (see analysis and discussion below). We report Greenhouse-Geisser adjusted values and use unadjusted degrees of freedom. As a general note, the ordering of confidence and no confidence block did not significantly affect performance.

Individual Difference Measures. Prior to conducting the principal analysis, we first examined correlations between measures of immediate memory and the alert, orienting, and executive components of ANT. Measures of the orientation network were significant correlated with both the alert network, $r^2 = .30$, $p < .001$, and the executive network, $r^2 = .07$, $p = .045$. The alert and executive network were not correlated, $r^2 = .00$, $p = .83$.

Positive correlations were observed for RSPAN and VSPAN, $r^2 = .17$, $p = .001$, RSPAN and ASPAN, $r^2 = .10$, $p = .02$, and ASPAN and VSPAN, $r^2 = .62$, $p < .001$. The r^2 values indicate that the two components of immediate memory (VSPAN and ASPAN) that require less attentional control were more strongly related than the active component (RSPAN) was to either.

The orientation component of the ANT correlated with both VSPAN, $r^2 = .07$, $p = .038$, and ASPAN, $r^2 = .06$, $p = .06$. Neither the alerting network nor the executive network had strong relationships with measures of immediate memory. Thus, given the positive correlations within measures of ANT and RSPAN, ASPAN, and VSPAN we collapsed within these measures. For the remainder of the study we refer to ANT measures as a whole and mean immediate memory score as immediate memory span (ISPAN).

Proportion Identification. Identification results for 2- and 3-category conditions are presented in Figure 1, Panel A through D. Together, VOT and the number of phonemic categories produced a significant change in ID performance, $F(14,798) = 30.62$, $MSE = .17$, $p< .001$, $\eta^2 = .35$, as well as a marginally significant main effect of VOT, $F(14,798) = 2.43$, $MSE = .17$, $p = .056$, $\eta^2 = .04$. This finding suggests a proficiency in the native-linguistic contrast of our listeners as well as sensitization to specific regions of the VOT continuum that are characteristic of categorical perception. Confidence condition alone also affected ID performance, $F(1,57) = 4.19$, $MSE = .05$, $p = .045$, $\eta^2 = .07$, again suggesting that the requirement of confidence might in fact alter performance.

Qualifying the above main effects and interactions was the three-way interaction between the number of phonemic categories, the location of the stimuli along the VOT continuum, and the confidence condition, $F(14,798) = 2.02$, $MSE = .03$, $p = .05$, $\eta^2 = .03$. A comparison between Panels A and C wherein confidence reports were required with Panels B and D wherein no reports were required presents a suggestive pattern. First, consider the 2-category conditions. In Panel A subjective confidence is at ceiling indicating considerable certainty in responses while ID performance is characterized by a sharp category boundary. In contrast, Panel B actually presents a less well-defined category boundary for listeners presented with a *native* linguistic contrast. In contrast to other studies that have compared performance in 2- and 3-category ID task (Pisoni et al.,1982; Schoenherr & Logan, 2013) listeners in the 2-category in this study received the same training block and feedback as those in the 3-category session. Thus, the provision of feedback appears to have altered performance.

Table 1. Mean identification performance for low- and high-ANT participants when the requirement of confidence was manipulated. Means for each region are presented. Standard errors are reported in parentheses.

VOTs	Low-ANT	High-ANT
-70 to -20	.68 (.05)	.65 (.06)
-10 to +20	.71 (.04)	.74 (.04)
+30 to +70	.89 (.03)	.88 (.04)

Next, a different pattern is evidenced when considering the 3-category condition. A comparison of Panels C and D suggests that feedback was processed in the same manner regardless of the requirement of confidence reports. This could be taken as evidence that the process of perceptual reorganization occurs below the level of subjective awareness. Moreover, it additionally implies that the acquisition of non-native speech sounds is unaffected by the requirements of performance monitoring. This suggests that using acoustic properties to develop a non-native contrast is primarily a function of implicit processes.

The individual differences measures used in the present study reveal a similar trend. Listeners’ aggregated ANT score co-varied with ID task performance and the location of the stimuli along the VOT continuum,

$F(14,798) = 2.62$, $MSE = .17$, $p = .04$, $\eta^2 = .04$. When assessed along the VOT continuum, our results suggest that the acoustic properties that differentiate stimuli along the VOT continuum require attentional capacity in order to learn and use phonemic categories (for the relationship of performance and dichotomized ANT scores for the three VOT regions of interest, see Table 1).

Table 2. Mean identification performance for low- and high-ISPAN participants when the requirement of confidence was manipulated. Standard errors are reported in parentheses.

Condition	High- ISPAN	Low-ISPAN
No Conf.	.67 (.04)	.77 (.04)
Conf.	.70 (.04)	.80 (.04)

ISPAN scores also co-varied with ID task performance and the requirement of confidence, $F(1,57) = 3.86$, $MSE = .05$, $p = .05$, $\eta^2 = .06$. Listeners appear to require greater immediate memory capacity in order to monitor performance, report confidence, and perform adequately in the ID task. A dichotomized set of results is presented in Table 2.

Confidence Reports. Two indices of subjective confidence are reported here: mean confidence and overconfidence bias. Mean confidence simply represented the average confidence in a response. Overconfidence bias represented the signed difference between mean subjective probability and mean proportion correct. For a further discussion of theoretical and computational issues, see Baranski and Petrusic (1994).

The ANCOVA of mean confidence revealed a significant effect of the number of number of phonemes, $F(1,57) = 15.89$, $MSE = 943.48$, $p< .001$, $\eta^2 = .22$, as well as its interaction with the location of a stimuli along the VOT continuum, $F(14,798) = 12.52$, $MSE = 288.13$, $p< .001$, $\eta^2 = .18$. In general, listeners expressed greater confidence when identifying stimuli using their native phoneme categories, with the greatest confidence reported in the /p/ category for listeners in both 2- and 3-category condition (see Figures 1A and 1C).

Overconfidence bias was similarly affected. A significant interaction was obtained between the number of phonemes and the location of a stimuli along the VOT continuum, $F(14,798) = 13.80$, $MSE = .10$, $p< .001$, $\eta^2 = .20$. By taking into account mean response accuracy, the measure of overconfidence indicates that listeners' metalinguistic awareness was determined by the representation of native phonemes. This pattern is evidenced in Figure 1 Panels A and C. In both cases mean confidence is greater whereas the reduction in confidence in the 3-category condition (Panel C) is less than the proportional decrease in accuracy. Support for a two-category representation of stimuli along the VOT continuum is evidenced by the reduction in confidence for stimuli in the /p^h-b/ range. Given that these stimuli were previously associated with the /b/ phoneme relative to the listeners' native phonemecategories, this suggests that listeners were aware of some acoustic properties in the /p^h-b/ range but that they compared them to the pre-existing phonemic structure.

No measure of subjective confidence co-varied with measures of attention or immediate memory. Relative to the results of the ID task, this suggests that although processing of metalinguistic information is dependent on immediate memory capacity, subjective awareness is not independently affected by capacity limitations.

Conclusion

The results of the present study provide further evidence for the ability of listeners to use the acoustic properties of stimuli along a speech continuum to identify exemplars defined in terms of non-native linguistic contrasts. Relative to previous studies (Pisoni et al. 1982; Schoenherr & Logan, 2013), greater uncertainty was observed in participants' identification response functions. The results of our manipulation do suggest that immediate response feedback allocates attention to specific psychophysical properties of the stimuli. This is clearly evidenced in the correct identification of the three training exemplars. Moreover, additional support comes from the observed performance decrements in the 2-category condition when training preceded the ID task. In their initial study, Pisoni et al. (1982) did not provide listeners in the 2-category condition with feedback. Instead, ID task responses were obtained in a no feedback, baseline condition. By providing listeners with feedback, we have demonstrated that the allocation of attention to the acoustic properties of stimuli can produce perceptual reorganization even when using a native linguistic contrast. Such feedback dependencies have elsewhere been linked with implicit learning (Ashby et al., 1998).

The nature of feedback processing, the dissociable effects of attention and immediate memory, as well as differences between identification performance and confidence reports lend support to a dual-process account of speech perceptions. Like Pisoni and Tash (1974), our results suggest multiple processing stages for the processing of acoustic and phonemic information. Because no task relies on a single process (Jacoby, 1991), acoustic and phonemic information are likely available to both implicit and explicit processes. Our results, however, allow for more specific claims. Attentional capacity appears to contribute to performance by determining whether acoustic or phonemic features are used for processing with greater attentional capacity resulting in increasingly graded identification functions. In contrast, immediate memory appears to be responsible for the retention of information obtained from the primary decision in order to monitor performance. As a result, such a process might be more important for self-regulation during learning in ecological settings than in the context of the present study.

References

Aslin, R. N., Pisoni, D. B., Hennessy, B. L., & Perey, A. J. (1981). Discrimination of voice onset time by human infants: New findings and implications for the effects of early experience. *Child Development*. *52*, 1135–1145.

Abramson, A., & Lisker, L. (1965). Voice onset time in stop consonants: Acoustic analysis and synthesis. Proceedings *of the Fifth International Congress on Acoustics*, Liege, A51.

Ashby, F. G., Alfonso-Reese, L. A., Turken, A. U., & Waldron, E. M. (1998). A neuropsychological theory of multiple systems in category learning. *Psychological Review*, 105, 442-481.

Baddeley, A. D. (1996). Exploring the central executive. *Quarterly Journal of Experimental Psychology, 49*A, 5-28.

Baranski, J. V., & Petrusic, W. M. (1994). The calibration and resolution of confidence in perceptual judgements. *Perception & Psychophysics*, *55*, 412-428.

Eimas, P. D. (1975). Auditory and phonetic coding of the cues for speech: Discrimination of the [r-1] distinction by young infants. *Perception & Psychophysics, 18,* 341-347.

Ellis, N. C. (1994). *Implicit and Explicit Learning of Languages*. London: Academic Press.

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General*, *128*, 309-333.

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. Journal of Cognitive Neuroscience, *14*, 340-7.

Gathercole, Willis, C. S., Emslie, H.,& Baddeley, A. D. (1992). Phonological memory and vocabulary developmentduring the early school years:A longitudinal study. *Developmental Psychology*, *28*, 887-898.

Goldstone, R. (1994). Influences of categorization on perceptual discrimination. *Journal of Experimental Psychology: General*, *123*, 178-200.

Haskins Laboratories (2011). Abramson/Lisker VOT Stimuli. Retrieved 01/12/2011. From http://www.haskins.yale.edu/featured/demo-liskabram/index.html /.

Hazan, V. & Barrett, S. (2000). The development of phonemic categorization in children aged 6-12. *Journal of Phonetics, 28*, 377-396.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language*, *30*, 513-541.

Jusczyk, P. (1989). Developing phonological categories from the speech signal. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological Development: Models, Research, Implications*. Timonium, MD: York.

Jusczyk, P.W. (2000). *The Discovery of Spoken Language*. Cambridge: MIT Press.

Liberman, A. M., Harris, K. S., Hoffman, H. S., & Griffith, B. C. (1957). The discrimination of speech sounds within and across phoneme boundaries. *Journal of Experimental Psychology*, *54*, 358-368.

Lisker, L., & Abramson, A. S. (1967). The voicing dimension: Some experiments in comparative phonetics. *Proceedingsof the 6th International Congress of PhoneticSciences.* Prague: Academia.

Miyake, A.,& Shah, P. (1999). *Models of working memory: Mechanisms of active maintenance and executive control*. Cambridge, England: Cambridge University Press.

Nosofsky, R. (1986). Attention, similarity, and the identification-categorization relationship. *Journal of Experimental Psychology: General*, *115*, 39-57.

Papagno, C., Valentine, T., & Baddeley, A. (1991). Phonological short-term memory and foreign-language vocabulary learning. *Journal of Memory and Language*, *30*, 331-347.

Pisoni, D. B., Aslin, R. N., Percy, A. J., & Hennessy, B. L. (1982). Some effects of laboratory training on identification and discrimination of voicing contrasts in stop consonants. *Journal of Experimental Psychology: Human Perception and Performance*, *8*, 297-314.

Pisoni D. B.,& Geers, A. (2000). Working memory in deaf children with cochlear implants: Correlations between digit span and measures of spoken language processing. *Annals of Otology, Rhinology,& Laryngology*, 109, 92–93.

Pisoni, D. B., & Tash, J. B. (1974) Reaction times to comparisons within and across phonetic categories. *Perception& Psychophysics, 15,* 285-290.

Posner, M. I. & Dehaene, S. (1994). Attentional networks. *Trends in Neuroscience*, *17*, 75-79.

Reber, A. S. (1967). Implicit learning of artificial grammars. *Journal of Verbal Learning & Verbal Behavior, 6,* 855-863.

Schoenherr, J. R., & Lacroix, G. (2013). Is double-dipping an alternative to double-dissociation?: Sampling two representational systems using a single task. *Proceedings of the 35th Annual Meeting of the Cognitive Science Society*, Berlin, Germany.

Schoenherr, J. R,. & Logan, J. (2013). Subjective awareness during cross-language speech perception: Attending unattended regions of an acoustic continuum. *Proceedings of the 35th Annual Meeting of the Cognitive Science Society*, Berlin, Germany.

Werker, J. F. (1989). Becoming a native listener. *American Scientist*, *77*, 54-59.

Werker, J. F. & Logan, J. S. (1985). Cross-language evidence for three-factors in speech perception. *Perception & Psychophysics*, *37*. 35-44.