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Research Note

Use of Crowdsourcing to Assess the Ecological Validity of Perceptual-Training Paradigms in Dysarthria

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Purpose: It has been documented in laboratory settings that familiarizing listeners with dysarthric speech improves intelligibility of that speech. If these findings can be replicated in real-world settings, the ability to improve communicative function by focusing on communication partners has major implications for extending clinical practice in dysarthria rehabilitation. An important step toward development of a listener-targeted treatment approach requires establishment of its ecological validity. To this end, the present study leveraged the mechanism of crowdsourcing to determine whether perceptual-training benefits achieved by listeners in the laboratory could be elicited in an at-home computer-based scenario.
Method: Perceptual-training data (i.e., intelligibility scores from a posttraining transcription task) were collected from listeners in 2 settings—the laboratory and the crowdsourcing website Amazon Mechanical Turk.
Results: Consistent with previous findings, results revealed a main effect of training condition (training vs. control) on intelligibility scores. There was, however, no effect of training setting (Mechanical Turk vs. laboratory). Thus, the perceptual benefit achieved via Mechanical Turk was comparable to that achieved in the laboratory.
Conclusion: This study provides evidence regarding the ecological validity of perceptual-training paradigms designed to improve intelligibility of dysarthric speech, thereby supporting their continued advancement as a listener-targeted treatment option.

Dysarthria, a motor speech disorder arising from neurological damage or disease, is characterized by deficits in the strength, range, timing, and/or tone of movements required for the production of speech. These movement disorders typically result in a reduction in overall intelligibility of the speech signal, or in other words, an intelligibility deficit. According to Duffy (2013), intelligibility is defined as the degree to which a listener is able to understand the acoustic signal produced by a speaker. What is important to note about this definition is that it embraces both speaker and listener contributions to the notion of speech intelligibility and potential intelligibility deficits. Yet despite the emphasis on both the speaker and the listener in the construct of speech intelligibility, the development of behavioral interventions to improve intelligibility of dysarthric speech has focused predominately on the speaker (Duffy, 2013). However, due to the progressive nature of some causes of dysarthria (e.g., amyotrophic lateral sclerosis, Huntington's disease), many speakers are not candidates for traditional speech-oriented intervention approaches (Duffy, 2013). Further, as Borrie, McAuliffe, and Liss (2012) have previously suggested, dysarthria (both progressive and nonprogressive) is frequently accompanied by physical, cognitive, and memory deficits—all of which can greatly reduce the individual's capacity to learn and maintain benefits from interventions that target the speaker. This highlights the significance of investigating methods for improving speech intelligibility that do not require speech-signal modifications on behalf of the individual with dysarthria.

Perceptual-training paradigms have been advanced as a means of improving intelligibility without placing demands on the speaker (Borrie, McAuliffe, & Liss, 2012; Lansford, Liss, Caviness, & Utianski, 2011; Liss, 2007). In brief, perceptual-training paradigms involve the use of a training or exposure task, in which written feedback may or may not be provided, to familiarize listeners with a noncanonical speech pattern. Following perceptual training, listeners often complete a transcription task in order to measure

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subsequent intelligibility of the noncanonical speech. Such training procedures have been shown to successfully improve intelligibility of foreign-accented (e.g., Bradlow & Bent, 2008; Clarke & Garrett, 2004; Sidaras, Alexander, & Nygaard, 2009), noise-vocoded (e.g., Davis, Johnsrude, Hervais-Adelman, Taylor, & McGettigan, 2005; Loebach, Bent, & Pisoni, 2008), time-compressed (Dupoux & Green, 1997), and dysarthric (e.g., Borrie, McAuliffe, Liss, Kirk, et al., 2012; Liss, Spitzer, Caviness, & Adler, 2002; Tjaden & Liss, 1995) speech. The proposed mechanism responsible for the perceptual gains following familiarization with noncanonical speech is that the exposure permits the listener to exploit the signal's indexical properties in order to extract regularities in the segmental and suprasegmental features and then to remap the deviant acoustic–phonetic information onto canonical representations stored in memory (Samuel & Kraljic, 2009). The indexical properties of a speech signal are those unrelated to its linguistic content and dependent on speaker-related factors (e.g., vocal-tract shape, fundamental frequency, and emotional state).

In a comprehensive review of the perceptual-learning literature and its applicability to neurologically disordered speech, Borrie, McAuliffe, and Liss (2012) provided a detailed account of how a perceptual-training approach to dysarthria management should be developed and included the following important steps:

1. Development of a rigorous evidence base
2. Examination of the cognitive–perceptual processes that underlie the perceptual gains
3. Evaluation of the familiarization conditions that optimize learning
4. Demonstration of long-term benefit

Much of Borrie's work published after this review sought to address these steps (e.g., Borrie, McAuliffe, Liss, Kirk, et al., 2012; Borrie, McAuliffe, Liss, O'Beirne, & Anderson, 2012, 2013), thereby laying the foundation for the development of a perceptual-training approach for the management of dysarthria. The ecological validity of perceptual training, however, has not been addressed. Although multifaceted in nature, ecological validity—a component of external validity—can be considered to reflect the extent to which data collected in laboratory settings generalize to more real-life settings (for a comprehensive review of the dimensions of ecological validity, see Schmuckler, 2001).[1] What is unknown at this point is if the training effects achieved in the laboratory, where the training conditions are under the direct control of the experimenter, can be elicited in more real-life settings, such as at home, in front of a personal computer or iPad without supervision. Moreover, the majority of the listeners recruited for laboratory-based perceptual-training studies have been college students, between the ages of 18 and 25 years. Whereas recruitment from student populations is relatively commonplace in speech-perception studies, it limits the generalizability of the findings to the broader population of listeners. Evidence of improved understanding of dysarthric speech in a more representative sample of listeners and in less constrained listening conditions would validate the ecological validity of perceptual-training protocols.

Crowdsourcing websites, such as Amazon's Mechanical Turk (MTurk), offer a mechanism for assessing the ecological validity of perceptual-training paradigms. MTurk is an online labor market in which requesters post jobs, called *Human Intelligence Tasks* (HITs), and workers choose to complete them for a small amount of pay. The website is geared toward businesses that are interested in outsourcing HITs to workers over the Internet. MTurk claims access to over 500,000 workers from 190 countries, fast turnaround times, accurate results, and low costs (https://requester.mturk.com). When we consider just the workers in the United States, a number of studies have noted that the MTurk participants tend to represent the U.S. population better than traditional university subject pools (e.g., Berinsky, Huber, & Lenz, 2012; Paolacci, Chandler, & Ipeirotis, 2010). Thus, MTurk serves as a promising platform for the recruitment and compensation of participants for online behavioral experiments. However, the quality of the data collected via the crowdsourcing website is a primary concern of behavioral researchers who are accustomed to collecting data in controlled laboratory environments. To be specific, researchers question whether effects demonstrated in the laboratory are replicable in the unconstrained setting associated with MTurk (Buhrmester, Kwang, & Gosling, 2011). Due to the relatively recent development of this technology, literature examining the differences between data collected in the laboratory and crowdsourcing forums is limited. However, emerging evidence suggests that the quality of behavioral data collected via MTurk may in fact be equivalent to that of data collected in the laboratory (Buhrmester et al., 2011; McAllister Byun, Halpin, & Szeredi, 2015; Saunders, Bex, & Woods, 2013; Sprouse, 2011). For example, and most germane to the current proposal, McAllister Byun et al. (2015) compared perceptual judgments of /r/ distortions in children with phonological impairment made by experienced listeners recruited to participate in the laboratory and novice listeners recruited via MTurk. Results revealed that the judgments made by experienced and MTurk listeners were largely equivalent. Whereas perception of dysarthric speech has yet to be investigated via crowdsourcing forums, the ready access to a more variable population and more real-world listening conditions offered by MTurk make this a suitable and innovative mechanism for evaluating the ecological validity of experimental paradigms.

[1]It is important to note that the construct of ecological validity is complex, and for the purposes of the present study a narrow definition was adopted. Here we assess the ecological validity of perceptual training by comparing data collected in the laboratory and in more real-life settings. However, the ecological validity of the training material and stimuli were not assessed directly in the present investigation.

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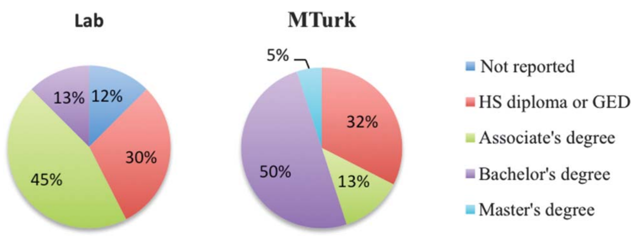
The purpose of the present investigation was to assess the ecological validity of perceptual-training paradigms in dysarthria (with regard to listener populations and listening conditions) by comparing perceptual-training data collected via MTurk to data collected within the laboratory. If perceptual-training paradigms are indeed an ecologically valid method to improve intelligibility of dysarthric speech, then the perceptual benefits associated with training in the laboratory should be comparable to those associated with training via Amazon's MTurk. We hypothesize that this is the case.

Figure 2. Education-level distribution of participants by training setting.



Method

Participants

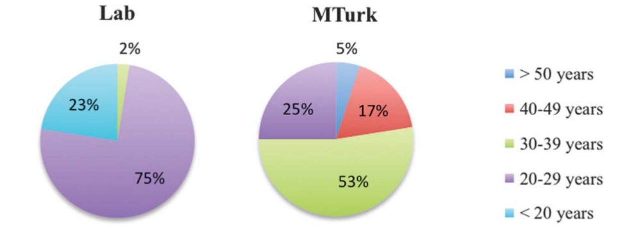
Laboratory Listeners

A total of 41 laboratory listeners were recruited from the undergraduate student population at Florida State University. All listeners had normal hearing and language–cognitive skills, per self-report, and North American English as their native language. Additional demographic information including age and highest education level earned was obtained from the listeners and is reported in Figures 1 and 2. Laboratory listeners received remuneration ($10) for participating.

MTurk Workers

A total of 50 MTurk workers were recruited from MTurk. Options available to investigators to enhance the quality of data collected via MTurk include the following: (a) adding "attention check questions" to identify participants who are noncompliant and (b) limiting participation to high-quality MTurk workers with high approval ratings designated by Amazon as Masters. In a recent study (Peer, Vosgerau, & Acquisti, 2014), Masters seldom missed attention check questions, and thus it was recommended that researchers should choose one or the other if obtaining high-quality data is a concern. Inclusion criteria for MTurk listeners in the present study included the status of Master, to keep data quality high and avoid introducing attention check questions to the training protocol. Participation in this study was also geographically restricted, so only workers with U.S.-based IP addresses were able to view and participate in the HIT. Also embedded in the task description was a disclaimer that participants should be native speakers of North American English. Demographic data regarding listener age, education level, native language, and history of hearing loss and cognitive or language disorders were also collected (age and education level reported in Figures 1 and 2). As per self-report, all participants were native speakers of North American English without a history of language or hearing disorders. Workers received remuneration ($2) in exchange for their participation.

Figure 1. Age distribution of participants by training setting.



Stimuli

Productions of a reading passage and a series of experimental phrases were used as speech stimuli in the present study, from three speakers (two male, one female) with moderate hypokinetic dysarthria secondary to Parkinson's disease, collected as part of a larger study conducted in the Motor Speech Disorders Lab at Arizona State University. In addition, the same speech samples obtained from three age- and sex-matched speakers without neurological disease or damage were collected and used in the present analysis. Detailed information related to the speech-sample recording procedures is given by Lansford and Liss (2014).

Speakers' audio-recorded productions of an adapted "Grandfather Passage" paired with orthographic transcription of the passage were used for the training phase. Recordings of speakers' productions of experimental phrases (26 unique phrases per speaker, 78 in total) were used for the test phase. The experimental phrases were created for a larger study in the Motor Speech Disorders Lab at Arizona State University and have been described previously (see Lansford & Liss, 2014; Liss, Utianski, & Lansford, 2013). In brief, the phrases contained six syllables and three to five mono- or disyllabic words, with low semantic transitional probability. The phrases alternated between strong and weak syllables, where strong syllables were defined as those carrying lexical stress in citation form.

Procedure

Experigen software (Becker & Levine, 2013) was used to program the experiment to facilitate web-based data collection from MTurk participants. The same computer-based program was used in both the crowdsourcing and

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laboratory settings. Listeners in the lab were seated in front of a computer screen and keyboard and were fitted with sound-attenuating headphones (Sennheiser HD 429). The room was quiet and set up to minimize auditory and visual distractions, and the experimenter remained present for the duration of the experiment. Prior to beginning the experiment, the experimenter ensured that the signal volume was set to a comfortable listening level for each listener and remained at that level for the duration of the task. Although MTurk workers were instructed that headphone use was required to complete the HIT, compliance could not be monitored. Nor could we control for the other laboratory-based requirements (e.g., silencing of cell phones and minimizing of other audio and visual distractions). The experimental protocol, however, was identical for both laboratory and MTurk listeners. All listeners participated in a training task followed by a posttraining transcription (test) task, and written instructions for each task were embedded into the computer-based program.

Training

Listeners were randomly assigned to one of two training conditions: experimental or control. Participants in the experimental training condition were instructed to listen to an adapted version of the "Grandfather Passage" produced by each of the three speakers with dysarthria and to follow along with the passage using the orthographic transcription provided on the computer screen. Participants in the control training condition completed an identical training task but listened to an adapted version of the "Grandfather Passage" produced by each of the three speakers who were neurologically intact.

Test

Immediately following training, all participants, regardless of training condition, completed a posttraining transcription task. Participants were instructed that they would hear a series of phrases produced by men and women with disordered speech. They were informed that although the phrases were composed of real English words, they would not necessarily make sense. The listeners were informed that they would hear each phrase only once and should type what they heard. They were encouraged to guess if unsure. Immediately following presentation of each phrase, listeners were given the opportunity to transcribe what they had heard using the computer keyboard. The phrases were presented in random order, and participants were given as much time as necessary to type their response.

Data Analysis

Transcription data from one laboratory listener and six MTurk workers were excluded due to noncompliance during the test phase, which was operationally defined as providing no response to more than 20% of the text phrases. Data from an additional four MTurk workers were excluded due to their advanced age (65 years or older and more than 3 *SD*s above the mean age for this group)[2] and, in one case, because the individual completed the HIT more than once (as determined by the IP address used). Thus, the usable data set consisted of 80 listener transcripts, 20 per combination of training condition and setting. First, listener transcripts were analyzed and scored for number of words correctly identified (words correct) by a trained research assistant in the Motor Speech Disorders Lab at Florida State University. After the initial scoring was completed, a second research assistant reviewed the scored transcripts for coding errors and made any necessary corrections. Procedures for scoring words correct were identical to those in previous studies on perception of dysarthric speech (e.g., Borrie, McAuliffe, Liss, Kirk, et al., 2012; Liss et al., 2002), with words scored as correct if they accurately matched the intended target or differed only by tense (*-ed*) or plurality (*-s*). Substitutions between "a" and "the" were scored as correct, as were misspellings and homophones. Words correct were tallied for each listener transcript and divided by total words possible, resulting in a single percent words correct score for each listener.

Results

A two-way analysis of variance with training condition (training vs. control) and training setting (lab vs. MTurk) as between-subjects factors was used to test the study hypotheses. Results of the analysis revealed a significant main effect for training condition, $F(1, 76) = 8.089$, $p = .006$, $\eta^2 = .096$, but not training setting, $F(1, 76) = 0.026$, $p = .842$. As illustrated in Figure 3, mean percent words correct scores for listeners assigned to the training condition (i.e., trained with dysarthric speech stimuli) were higher than the scores for listeners assigned to the control condition (i.e., trained with healthy speech stimuli), irrespective of training setting. In fact, mean percent words correct scores for laboratory and MTurk listeners were virtually identical.

Discussion

The purpose of the present investigation was to assess the ecological validity of perceptual-training paradigms by comparing training data collected in the laboratory to data collected from Amazon's Mechanical Turk crowdsourcing website. It is unsurprising that the results of this study replicate previous findings that reported intelligibility gains for listeners familiarized briefly with dysarthric speech (Borrie, McAuliffe, Liss, Kirk, et al., 2012; Borrie, McAuliffe, Liss, O'Beirne, & Anderson, 2012, 2013; Liss et al., 2002). More important, however, this study revealed that intelligibility

[2]Although three older listeners were excluded in the present analysis, we acknowledge the importance of investigating the effects of perceptual training in this population, because spouses and caregivers of individuals with dysarthria are often older adults. For this reason, a perceptual-training investigation targeting listeners in this demographic is currently under way.

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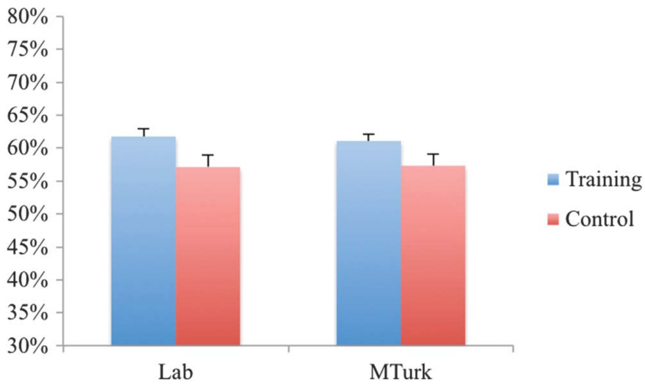
Figure 3. Listeners' mean percent words correct and standard error bars by training condition (training vs. control) and training setting (lab vs. MTurk).



gains for listeners familiarized with dysarthric speech were comparable across the two training settings. That is, despite the substantial differences in demographic variability (i.e., age, education level) and environmental control between listening conditions in the laboratory and crowdsourced settings, the quality of the output data was equivalent. Thus, the results of the present study extend the methodology used in previous perceptual-training studies conducted in the laboratory to a more real-life setting.

Telepractice and computer-based home interventions in speech-language pathology are becoming increasingly common (American Speech-Language Hearing Association, 2016; for a recent review of the literature, see Edwards, Stredler-Brown, & Houston, 2012). Several recent studies have compared therapeutic outcomes for individuals with dysarthria who received treatment either in person or online and have demonstrated noninferiority of web-based delivery (e.g., Constantinescu et al., 2011; Halpern et al., 2012; Howell, Tripoliti, & Pring, 2009). For multiple reasons, including the demands associated with caring for persons with dysarthria, limited access to experts with the specialized training in many areas of the country, travel, and cost, it may be impractical and perhaps unfeasible for a spouse or caregiver to undergo perceptual training in a laboratory or clinic. In such instances, a computer-based perceptual-training protocol that can be carried out within the home environment would offer a convenient and affordable option.

In recent years, considerable work has been conducted to advance perceptual training as a means of improving intelligibility by exploiting the malleability of the listener's perceptual system. However, a number of critical questions must be addressed before perceptual training can be considered a viable treatment option. For example, it has been reported that caregivers adapt passively, over time and without direct intervention, to become better perceivers of dysarthric speech (DePaul & Kent, 2000). Nevertheless, it has been well documented that for naïve listeners, active (or explicit) methods of perceptual training result in greater perceptual gains than passive listening (e.g., Borrie, McAuliffe, Liss, Kirk, et al., 2012; Davis et al., 2005). What is not yet known is the extent to which active perceptual-training approaches would improve the speech understanding of listeners already familiar with a speaker (or speakers) with dysarthria. Thus, future work in perceptual training should target listeners already familiar with dysarthric speech, including spouses, caregivers, and speech-language pathologists.

Individual differences in the magnitude of perceptual gain following training are another underexplored issue that requires attention in future research. In the present study, intelligibility scores for listeners trained with speakers with dysarthria range from 51% to 71%. Recent studies have shown that substantial individual differences in speech-perception abilities emerge under adverse listening conditions, including listeners recognizing dysarthric (Borrie, 2015) and accented (Janse & Adank, 2012) speech. How these perceptual differences continue to manifest after specific training warrants investigation, as do the cognitive factors that may predict one's ability to benefit, optimally, from a perceptual-training paradigm.

The present study used three speakers who shared a common dysarthria type and level of severity. It will be important for future research to consider the extent to which training with one speaker with dysarthria generalizes to another speaker (or speakers) with shared speech characteristics. Demonstration of cross-speaker generalization in dysarthria has important clinical implications, because communicative interactions between speakers with dysarthria and clinicians (and other medical professionals) could be improved if perceptual training targeting dysarthric speech is shown to generalize to novel speakers.

The present results support the use of crowdsourcing platforms, such as Amazon's Mechanical Turk, for behavioral data collection in research into communication science and disorders. Crowdsourcing forums provide access to hundreds of thousands of listeners, facilitating acquisition of data from a diverse subject pool. Data collection is also both extremely cost-effective and time efficient. For example, in the present study we collected data from 41 laboratory participants over the course of 6 months and compensated them at a rate of $10 per hour. In contrast, data from all 50 of the MTurk participants were collected in less than 6 hr, and workers were compensated $2 for their effort. Although data-point exclusions were higher in the cohort of MTurk workers, this disadvantage did not come close to canceling out the substantial cost benefit associated with the use of crowdsourcing forums for collection of behavioral data. The fact that the quality of the data collected via MTurk was comparable to that of the data collected in the lab—consistent with the results of McAllister Byun et al. (2015)—supports crowdsourcing as a valuable tool to collect behavioral data in communication sciences and disorders.

Conclusion

Here we provide empirical evidence for the ecological validity of perceptual-training paradigms using crowdsourcing. This is an important step in advancing perceptual-training

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methods for improving intelligibility of persons with dysarthria. We add to the growing body of evidence supporting the development of perceptual training for improving the intelligibility of persons with dysarthria and highlight crowdsourcing as a valid and convenient tool for conducting experimental research in the discipline of communication science and disorders.

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