



The study of speech naturalness in communication disorders: A systematic review of the literature

Marie Klopfenstein, Kelsey Bernard & Claire Heyman

To cite this article: Marie Klopfenstein, Kelsey Bernard & Claire Heyman (2020) The study of speech naturalness in communication disorders: A systematic review of the literature, Clinical Linguistics & Phonetics, 34:4, 327-338, DOI: [10.1080/02699206.2019.1652692](https://doi.org/10.1080/02699206.2019.1652692)

To link to this article: <https://doi.org/10.1080/02699206.2019.1652692>



Published online: 28 Aug 2019.



Submit your article to this journal [↗](#)



Article views: 189



View related articles [↗](#)



View Crossmark data [↗](#)



The study of speech naturalness in communication disorders: A systematic review of the literature

Marie Klopfenstein^a, Kelsey Bernard^b, and Claire Heyman^c

^aDepartment of Applied Health at Southern Illinois University Edwardsville, Southern Illinois University Edwardsville, Edwardsville, IL, USA; ^bPhysiological Sciences Program at University of Arizona, University of Arizona, Tucson, AZ, USA; ^cIn-Patient Rehab Department at Carle Foundation Hospital, Carle Foundation Hospital, Urbana, IL, USA

ABSTRACT

The concept of speech naturalness is used widely in clinic and research applications. Unfortunately, the lack of consistency in research methods means that comparing findings between studies is difficult at best. In order to better understand the state of research on speech naturalness in communication disorders and quantify these impressions, this study looks at publications from the last 18 years in a systematic manner. A literature search for the exact phrase “speech naturalness” of the PubMed/MEDLINE, EBSCO, and ASHAWire databases was conducted. Articles included in the review were studies of communication and communication disorders published between 1990 and the end of 2014, in English, and in a peer-reviewed journal. 63 articles were selected and coded using a coding sheet adapted from a prior systematic review on intelligibility and cleft palate. Speech naturalness is an object of study in many subfields of communication disorders. Several concerns were raised as a result of the review, including the reliability and validity of measures, inadequate definitions of terminology, lack of detail in method descriptions, and the need to address relationships between naturalness and other variables included in the studies. Future studies should more carefully report methods and operational definitions used and more studies examining the relationship between naturalness and other speech variables in a variety of communication disorders are greatly needed.

ARTICLE HISTORY

Received 31 January 2019
Revised 31 July 2019
Accepted 2 August 2019

KEYWORDS

Speech naturalness; speech disorders; hearing disorders

Introduction

Naturalness is an overall, or global, measure of an individual’s speech that is closely related to the individual’s prosody and intelligibility. As one recent definition of naturalness states, “Speech is natural if it conforms to the listener’s standard of rate, rhythm, intonation, and stress patterning, and if it conforms to the syntactic structure of the utterance being produced” (Yorkston, Beukelman, Strand, & Bell, 1999, p. 464). The concept of naturalness is used widely in clinic and research applications. For example, naturalness has been used in the investigation of perceptual differences between the speech of non-stutterers and post-treatment stutterers (Ingham & Onslow, 1985; Onslow & Ingham, 1987; Runyan, Hames, & Prosek, 1982; Sacco, Metz, & Schiavetti, 1992), the relationship between acoustic variables and natural speech (Metz, Schiavetti, & Sacco, 1990), and the

effect of fingerspelling and perceived naturalness of speech during simultaneous communication (Schiavetti, Whitehead, Whitehead, & Metz, 1998), to name only a few.

Speech naturalness has been described in various ways for different speech disorders, sometimes with roughly equivalent terms such as acceptability. In the literature on stuttering, Martin, Haroldson, and Triden (1984, p. 53) describe unnatural speech as sounding “slow, paced, or monotonous and can be discriminated from [the speech of nonstutterers].” Manning (2001) describes such speech as uncomfortable to listen to and as having features that can distract the listener from fully attending to the content of the message. Conversely, Witzel (1995) defines acceptability as the listener’s subjective impression of how pleasing the speech is. The latter definition is especially vague and could invite listeners to rate non-impaired speech as unacceptable based on preferences for regional dialects, which may be a valid consideration in certain contexts, but is not a therapeutically useful one for speech-language pathologists. A critical review of studies of speech disorders associated with cleft palate found confusion and inconsistency between terms like intelligibility, acceptability, naturalness, severity, and proficiency (Whitehill, 2002). In order to deal with this issue, a more recent study on intelligibility and acceptability in cleft palate speech (Whitehill & Chun, 2002) adopted Southwood and Weismer (1993) definition of acceptability as speech that is functional and that fulfills at least the minimum requirements for a communicative need.

The literature on dysarthria often uses the terms bizarreness and naturalness. Initially, these terms were conceptualized as measures of severity of speech impairment and level of disability, respectively. Darley, Aronson, and Brown (1969, p. 251) define bizarreness as a “rating of degree to which overall speech calls attention to itself because of its unusual, peculiar, or bizarre characteristics.” More recent definitions of naturalness have added an emphasis on features of prosody in their descriptions. Yorkston, Beukelman, Strand, and Hakel (2010, p. 288) state “speech is natural if it conforms to the listener’s standards of rate, rhythm, intonation, and stress patterning, and if it conforms to the syntactic structure of the utterance being produced. It is considered unnatural or bizarre if it deviates from the expected or is unconventional in terms of these prosodic features.” A similar definition by Yorkston, Beukelman, Minifie, and Sapir (1984) includes voice quality and intensity adjustments – independently from stress patterning – to the prosodic features of speech naturalness. These more recent definitions present naturalness as the polar opposite of bizarreness and assume that listener’s perceptions of naturalness are primarily related to prosodic variables.

The interchangeable use of the terms naturalness, bizarreness, acceptability, and normalcy in the literature makes it difficult to compare the results of various studies in order to determine what perceptual criteria listeners may be using to determine ratings. One study of the dysarthria associated with Amyotrophic Lateral Sclerosis found strong correlations between all of these dimensions, suggesting that they may not be perceived as different qualities of dysarthric speech (Southwood & Weismer, 1993). Another major problem with these definitions is that they have not been validated in terms of the variables they purport to be primarily related to. There have been calls for research to determine what aspects of speech – and the relative importance of these aspects – contribute to naturalness ratings in order to better establish treatment priorities (Linebaugh & Wolfe, 1984; Metz et al., 1990; Southwood & Weismer, 1993; Yorkston et al., 1999).

The more specific descriptions of naturalness share an emphasis on prosodic features as an important aspect of speech naturalness, which is supported by the results of studies that examine naturalness in various speech disorders discussed in the following section.

Including prosody in the definition of naturalness may be important in order to differentiate naturalness from other perceptual measures like intelligibility. This approach is supported by studies in which disordered speech has been rated less natural than normal speech, even in the absence of segmental-level errors (Ingham & Onslow, 1985; Onslow & Ingham, 1987; Runyan et al., 1982; Sacco et al., 1992). This research suggests that listeners are basing their judgments of naturalness, in part at least, on suprasegmental aspects of speech. Although investigators have linked various speech characteristics to unnatural speech through acoustic and experimental studies (Bellaire, Yorkston, & Beukelman, 1986; Metz et al., 1990; Simmons, 1983; Whitehill & Chun, 2002), how these features interact in order to result in unnatural sounding speech is complex and only partly understood. Information about suprasegmental features often helps to explain the perceived lack of naturalness (Yorkston et al., 1999).

Naturalness has been investigated in many different types of speech and speech disorders. One major example is stuttering, as numerous studies have found that the speech of post-treatment adults is perceptually unnatural sounding when compared to normal speakers (Ingham, Gow, & Costello, 1985; Ingham & Packman, 1978; Metz et al., 1990; Onslow, Hayes, Hutchins, & Newman, 1992; Runyan & Adams, 1978, 1979). Especially striking are studies that have found that even in the absence of stuttering-like disfluencies, the speech of stutterers is still perceived as less natural sounding than the speech of non-stutterers (Ingham & Onslow, 1985; Onslow & Ingham, 1987; Runyan et al., 1982; Sacco et al., 1992). The only published study on acoustic aspects of speech and naturalness in stuttering found a significant relationship between voice onset time (VOT), sentence duration, and speech naturalness in the speech of individuals who stutter (Metz et al., 1990).

To date, there has been only one study on naturalness in the area of augmentative and alternative communication. Ratcliff, Coughlin, and Lehman (2002) looked at the effects of rate, pitch, and pause on ratings of speech naturalness on a particular type of voice output communication aid, DECTalk speech. The authors found that while listeners consistently found synthesized speech less natural than human speech and attributed their ratings to differences in pitch, rate, and pauses, only manipulations of speech rate and pause time resulted in significantly different naturalness ratings in subsequent experiments. The authors suggested that pitch may have not influenced naturalness ratings because only average pitch was manipulated, which did not produce perceptions of monotone speech or highly variable pitch.

Most research on cleft palate speech has focused on comparisons between its characteristics and intelligibility rather than naturalness (Whitehill, 2002). One recent study (Whitehill & Chun, 2002) looked at intelligibility and acceptability in speakers with cleft palate. The results indicated that intelligibility and acceptability are related, but not identical measures. Acceptability strongly correlated with nasality, while reduced articulatory proficiency had a much weaker effect.

Speech naturalness has been predominantly investigated in dysarthria and stuttering, although it has the potential to be a fruitful area of research in other speech disorders. The issue of naturalness in the speech of individuals with Aphasia or Apraxia of Speech (AOS) remains relatively unexplored, although both disorders have speech characteristics that could lend themselves well to naturalness ratings. Aphasics with right hemisphere damage characteristically are aprosodic, with reduced fundamental frequency and intensity contours throughout utterances and equal syllable durations (Kent & Rosenbek, 1982). Such

individuals have also been found to have reduced clause and utterance lengths (Cooper et al., 1984). One of the primary symptoms of AOS is prosodic disturbance. Apraxic speakers exhibit uniform syllable durations and fundamental frequency patterns (Kent & Rosenbek, 1982). Other prosody disturbances include slow speaking rate, reduced use of stress patterning, prolonged or inappropriate intersyllabic or interword pauses, and articulatory prolongation (Darley, Aronson, & Brown, 1975; Kent & Rosenbek, 1983; McNeil, Liss, Tseng, & Kent, 1990; Odell, McNeil, Rosenbek, & Hunter, 1990; Ryalls, 1981; Strand & McNeil, 1996; Wertz, LaPointe, & Rosenbek, 1984). In a study of an individual with AOS following a left hemisphere stroke, Tjaden (2000) found that equal syllable duration resulted in reduced speech naturalness. Similarly, the speech of hearing-impaired individuals is often characterized by prosodic disturbances. The speech of children with cochlear implants has been described as having inappropriate stress, pausing, and intonation (Lenden & Flipsen, 2007). Monotone speech and excessive variations in pitch have both also been observed in this population (Parkhurst & Levitt, 1978). Despite these well-known characteristics, researchers have mainly investigated the naturalness of speech output of hearing aids (Marzinzik, 2000) rather than the speech naturalness of the hearing-impaired themselves. One study (Osberger, 1987) examined the acceptability of subject's vowel productions in monosyllabic CVC words after systematic speech training.

In summary, when reviewing the literature on speech naturalness, several issues become apparent. The psychological validity of the measure has been shown through the reliably consistent judgments of naturalness on 9-point Likert scale (Ingham et al., 1985; Onslow, Adams, & Ingham, 1992), yet naturalness is often inconsistently defined, if defined at all. In addition, naturalness is at times used interchangeably or inconsistently with terms like normalcy, bizarreness, and acceptability. Another issue is the need for more research on what aspects of speech contribute to perceived naturalness (Linebaugh & Wolfe, 1984; Metz et al., 1990; Southwood & Weismer, 1993; Yorkston et al., 1999). Finally, methods for assessing naturalness vary widely between studies. In order to better understand the state of research on speech naturalness in communication disorders and quantify these impressions, this study looks at publications from the last 14 years in a systematic manner.

The present study aims to address three research questions: (1) how is speech naturalness measured across various studies; (2) are we adequately distinguishing naturalness from other global measures of speech output; and (3) how are we increasing our understanding of what aspects of speech contribute to naturalness judgments?

Method

Using the PubMed/MEDLINE, EBSCO, and ASHAWire databases, a literature search for the exact phrase "speech naturalness" was conducted. Articles considered for inclusion in the review were studies of communication and communication disorders published between 1990 and August 2018, in English, and in a peer-reviewed journal. This search resulted in 141 journal articles. Of these, 78 articles were either discarded as duplicates, considered not relevant to the current review because they did not include any measure considered to be a naturalness measure, or were tutorials rather than research articles. The

remaining 63 articles were selected to be read and coded using a coding sheet developed for this study.

The coding sheet was adapted from a systematic review of intelligibility assessment in cleft palate research (Whitehill, 2002) and addressed the following questions: (1) was another global measure of speech output (such as intelligibility) included; (2) was naturalness defined; (3) how was naturalness measured; (4) was there any attempt to explain naturalness deficits by examining the correlation between naturalness and other speech variables; (5) what disorder was the focus of the study; (6) what type of speech sample was used for assessing naturalness; (7) how many listeners were used to assess naturalness; (8) what type of listeners were used; and (9) was listener reliability reported?

All articles were coded by the authors of this study and then re-coded several months after the original coding. Intrajudge reliability for coding was above 97% for all categories. Where coding judgments differed, the coding was discussed and reviewed until a consensus was reached.

Results

63 articles covering the years 1990 to 2018 were reviewed. The articles covered a wide variety of non-disordered and disordered speech, as well as different modes of communication. The nature of the speech focused on in each study is summarized in Table 1.

The majority of studies (39 or 62%) concerned fluency disorders like stuttering and cluttering. Two studies (3%) looked at the speech produced by AAC devices. Alaryngeal speech and audiology were the focus of three (5%) and four (6%) of the studies each, respectively. Ten studies (16%) were concerned with motor speech disorders. One study (2%) looked at naturalness related to tracheostomies and voice each. The remaining three studies (5%) were focused on establishing normative values.

Other global measures used

45 (71%) of the studies did not examine any other global measure of speech output. The remaining 18 (29%) did examine at least one; some included two different global measures. These measures are given in Table 2.

In examining these measures, there is potential overlap with the measure of naturalness depending on how one defines naturalness. The difficulty with defining naturalness and potentially overlapping and inconsistent terminology will be addressed later.

Table 1. Primary focus of studies reviewed.

Primary Focus	Number of Studies
AAC	2
Alaryngeal Speech	3
Audiology	4
Fluency Disorders	39
Motor Speech Disorders	10
Normal Speech	3
Tracheotomy	1
Voice	1

Table 2. Global measures studied in addition to naturalness.

Global Measure	Number of Studies
Intelligibility	10
Listening effort	3
Acceptability	2
Normalcy	1
Speech effort	1
Listener comfort	1
Voice quality	2
Rhythmicity	1
Pleasantness	1

Definitions of naturalness

43 out of 63 studies (68%) did not include an operational definition of naturalness, although the measure was used as a variable. However, some of these studies may have given naturalness raters some sort of criteria that was not provided in the write up of the research. If this is the case, it poses a significant challenge to any who wish to test a study's reproducibility.

Those that did include definitions had varying definitions or utilized a negative definition of naturalness (e.g., as what naturalness is not – see Andrews et al., 2012). A few studies provided detailed descriptions of naturalness for their raters, including examples of both natural and unnatural speech (Craig et al., 1996). Some of the definitions given defined naturalness at least in part as containing few disfluencies and/or perceived effortless speech (Ingham, Warner, Byrd, & Cotton, 2006; McLeod & Searl, 2006; Tamplin, 2008). Other definitions included prosodic and suprasegmental aspects of speech, such as intonation, rate, loudness, rhythm, stress patterns, and voice quality (Eadie & Doyle, 2002; Spencer, Morgan, & Blond, 2009; Stocks, Dacakis, Phyland, & Rose, 2009; Tamplin, 2008; Yorkston, Hammen, Buekelman, & Traynor, 1990). One defined naturalness as a combination of intelligibility – another global measure – and speech production (Shikani & Dietrich-Burns, 2012). The remaining studies utilized extremely simple, and to some extent circular, definitions, stating that naturalness is essentially natural or normal speech (Coughlin-Woods, Lehman, & Cooke, 2005; Eadie, Doyle, Hansen, & Beaudin, 2008; Ratcliff et al., 2002; Tjaden, 2000; Tse, Wong, Ma, Whitehill, & Masters, 2013).

Method of measuring naturalness

The most common method of measuring naturalness was with a 9 point Likert scale, with the scale being used in 40 (63%) of the studies reviewed. In this scale, a score of 9 indicates highly unnatural sounding speech and 1 indicates highly natural speech, with scores of varying levels of naturalness available in between. The next most common method (used in 22 studies or 35%) was some other type of Likert scale, with scales varying from 4 to 100 points. Other methods include binary scales (4 or 6%), in which the choice was between natural and unnatural ratings, and Direct Magnitude Estimation (2 or 3%). In DME, listeners were provided with an example baseline and asked if rating samples were twice as natural, half as natural, etc., and assigned a score accordingly. Finally, one study

(2%) used qualitative descriptions of speech and determined naturalness from these descriptions.

Correlations between naturalness and speech variables

This factor was examined to determine the extent to which the relationship between naturalness and other variables has been investigated. It can be considered an indication of how researchers are attempting to increase our understanding of what listeners use to make their judgments of naturalness. The majority of studies reviewed (44 or 70%) did not attempt to correlate measurements of naturalness with another variable. The remaining 19 studies (30%) did include correlations with one or more of the following variables: temporal measures (including speech rate, sentence duration, word duration, diphthong duration, and intervals before and after words), stutter-free syllables per minute, frequency of part-word repetitions, phonation type, fundamental frequency, monopitch, fluency-inducing condition, speech effort, severity, dialect, percentage of syllables stuttered, and rhythmicity.

Speech sample used

There was a large amount of variability in how studies reported what kind of speech sample they used. It was not possible to categorize or count types of speech samples by study, since many types could possibly overlap without more detailed descriptions in studies’ methods sections (e.g., a recorded telephone conversation would presumably involve conversational speech, but without a more detailed methods section one cannot be certain). Example descriptions of sample types are target words, pre/posttreatment, picture description task, stutter-free speech, sentences, monologue, spontaneous speech, reading passage, and conversational speech. Some studies defined the sample by the length of the sample or the type of recording (e.g., telephone, video, etc.) as well.

Number and types of listeners

Studies varied in the number of listeners used to assess naturalness, as shown in Table 3. All but one study reported how many listeners were used. A majority of studies used either six to twenty listeners or five or fewer listeners (21 or 33% each). Some studies used as many as over 50 listeners (9 or 14%).

The majority of studies (26 or 41%) used naive listeners. 25 studies (40%) used listeners who had some expertise in speech and language, either because they were practicing speech-language pathologists, students (graduate or undergraduate) in speech-language pathology,

Table 3. Number of listeners.

Number of Listeners	Number of Studies
5 and under	18
6 to 20	21
21 to 49	14
over 50	9
unspecified	1

Table 4. Types of listeners.

Type of Listener	Number of Studies
Naïve	26
Expert	25
Mixed	10
Unspecified	2

Table 5. Reports of listener reliability.

Reliability Reported	Number of Studies
Inter-rater only	8
Intra-rater only	2
Inter- and intra-rater	34
None	19

and/or trained listeners. Ten (16%) studies used a mixture of listeners (i.e., a panel of speech-language pathologists and a panel of naïve listeners). Only two studies did not specify the type of listener. A summary of types of listeners used is provided in Table 4.

Reliability reports

44 of the studies reviewed (70%) reported the reliability of their naturalness measurements. Studies were included in this number if they reported interjudge and/or intrajudge reliability; a majority of studies included both (34 or 54%). A summary of reliability reporting in the studies is given in Table 5. 19 articles (30%) included no information about the reliability of naturalness measures.

Discussion

63 studies published in recent years that included the measurement of speech naturalness were identified and reviewed. The studies had a wide range of focus, covering everything from normal speech to AAC to fluency disorders. However, several significant concerns were raised due to this review.

One concern relates to the reliability and validity of measurements. The importance of including interrater and intrarater reliability in measuring speech has been stated by other authors (D'Antonio & Scherer, 1995; Wyatt et al., 1996). Despite this, 30% of the studies reviewed included no reports on the reliability of their measurements. Although most of the studies (54%) included both inter- and intrarater reliability, the lack of reporting could cast doubt on how dependable the measurements were. Validity of measurements is related to construct validity, which is the extent to which a tool measures an underlying concept. This is difficult, or even impossible, to ensure when a standardized definition of the concept does not exist. While this problem is not limited to just the concept of speech naturalness in communication disorders, it is very present, as shown by the review. 68%, a majority of the studies reviewed, did not include a definition of naturalness, despite measuring it. Those that did provide a definition utilize varying definitions, often

depending on the speech disorder involved. Unfortunately, this makes it impossible to compare results across studies, as one cannot be certain that the same entity was measured.

The lack of unified definition relates to the tension between parsimony and thick description when studying a real-life phenomenon like speech naturalness. The two do not necessarily need to be mutually exclusive in any one theory or explanation. Yet there are situations in which a more parsimonious approach, in which a more superficial description leads to easier understanding, is more appropriate and other situations in which it would be more appropriate to err on the side of accuracy by attempting a more complex description of the subject of study, even if it is more difficult to grapple with. Given the advances in the field of speech-language pathology and current emphasis on evidence-based practice, it seems that the latter approach here is more than justified. It may be possible to have one very broad definition of speech naturalness that can cover all types of speech disorders, but it is likely that much more work has to be done to make more accurate and detailed definitions of speech naturalness according to disorder. Either way, researchers and clinicians would benefit from accurate, agreed upon definitions.

Another concern was that the type of speech sample used for measurement varied widely and was often not possible to determine exactly due to lack of detail in method descriptions. From this review, it can be seen that a large variety of methods are used to measure naturalness and there are no recommended protocols. Unfortunately, the lack of detailed description makes replication studies, a basic tool of science, unfeasible. In addition, there is some indication that different types of speech samples (e.g. reading passages versus spontaneous speech) elicit different naturalness ratings by listeners (Klopfenstein, 2016). Until the relationship between speech sample type and naturalness ratings is better understood, future research should report detailed descriptions of methods used so that comparison of results and replications studies are possible.

A final aspect of concern relates to the lack of attempt to relate naturalness and other aspects of speech. Our understanding of what listeners use to evaluate naturalness is still very limited, as very few studies include correlations. Most studies did not attempt to determine its relationship to other variables reported (70%), despite naturalness being included as a measure. A better understanding of this relationship could improve therapeutic decision-making, if targeting intelligibility before naturalness, as suggested by Whitehill (2002). Another possibility is that with this insight clinicians could better predict how different treatment approaches, depending on what is targeted, affect naturalness and vice versa.

In summary, the review indicates that speech naturalness is an object of study in many subfields of communication disorders. Each of these fields has the potential to serve as an important contributor to understanding what exactly influences perceptions of naturalness, a measure shown to be psychologically valid but difficult to describe thus far. Unfortunately, the lack of consistency between methods used in different studies means that comparing findings is difficult at best. Future studies should more carefully report methods and operational definitions used and more studies examining the relationship between naturalness and other speech variables in a variety of communication disorders are greatly needed.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

- Andrews, C., O'Brian, S., Harrison, E., Onslow, M., Packman, A., & Menzies, R. (2012). Syllable-timed speech treatment for school-age children who stutter: A phase I trial. *Language, Speech, and Hearing Services in Schools*, 43, 359–369. doi:10.1044/0161-1461(2012/11-0038)
- Bellaire, K., Yorkston, K. M., & Beukelman, D. R. (1986). Modification of breath patterning to increase naturalness of a mildly dysarthric speaker. *Journal of Communication Disorders*, 19(4), 271–280.
- Cooper, W. E., Soares, C., Nicol, J., Michelow, D., & Goloskie, S. (1984). Clausal intonation after unilateral brain damage. *Language and Speech*, 27(1), 17–24.
- Coughlin-Woods, S., Lehman, M. E., & Cooke, P. A. (2005). Ratings of speech naturalness of children ages 8–16 years. *Perceptual and Motor Skills*, 100(2), 295–304. doi:10.2466/pms.100.2.295-304
- Craig, A., Hancock, K., Chang, E., McCready, C., Shepley, A., McCaul, A., ... Masel, C. (1996). A controlled clinical trial for stuttering in persons aged 9 to 14 years. *Journal of Speech & Hearing Research*, 4, 808–826. doi:10.1044/jshr.3904.808
- D'Antonio, L. L., & Scherer, N. J. (1995). The evaluation of speech disorders associated with clefting. In R. J. Shprintzen & J. Bardach (Eds.), *Cleft palate speech management: A multidisciplinary approach* (pp. 176–210). St. Louis, MO: Mosby.
- Darley, F. L., Aronson, A. E., & Brown, J. R. (1969). Differential diagnostic patterns of dysarthria. *Journal of Speech and Hearing Research*, 12(2), 246–269.
- Darley, F. L., Aronson, A. E., & Brown, J. R. (1975). *Motor speech disorders*. Philadelphia: W. B. Saunders Co.
- Eadie, T., Doyle, P., Hansen, K., & Beaudin, P. (2008). Influence of speaker gender on listener judgments of tracheoesophageal speech. *Journal of Voice*, 1, 43–57. doi:10.1016/j.jvoice.2006.08.008
- Eadie, T. L., & Doyle, P. C. (2002). Direct magnitude estimation and interval scaling of naturalness and severity in tracheoesophageal (TE) speakers. *Journal of Speech, Language, and Hearing Research*, 45(6), 1088–1096. doi:10.1044/1092-4388(2002/087)
- Ingham, R. J., Gow, M., & Costello, J. M. (1985). Stuttering and Speech Naturalness: Some Additional Data. *Journal of Speech and Hearing Disorders*, 50(2), 217–219.
- Ingham, R. J., & Onslow, M. (1985). Measurement and modification of speech naturalness during stuttering therapy. *Journal of Speech and Hearing Disorders*, 50(3), 261–281.
- Ingham, R. J., & Packman, A. C. (1978). Perceptual assessment of normalcy of speech following stuttering therapy. *Journal of Speech and Hearing Research*, 21, 63–73.
- Ingham, R. J., Warner, A., Byrd, A., & Cotton, J. (2006). Speech effort measurement and stuttering: Investigating the chorus reading effect. *Journal of Speech, Language, and Hearing Research*, 49(3), 660–670. doi:10.1044/1092-4388(2006/048)
- Kent, R. D., & Rosenbek, J. C. (1982). Prosodic disturbance and neurologic lesion. *Brain and Language*, 15(2), 259–291.
- Kent, R. D., & Rosenbek, J. C. (1983). Acoustic patterns of apraxia of speech. *Journal of Speech and Hearing Research*, 26, 231–249.
- Klopfenstein, M. (2016). Speech naturalness ratings and perceptual correlates of highly natural and unnatural speech in hypokinetic dysarthria secondary to Parkinson's disease. *Journal of Interactional Research in Communication Disorders*, 7(1), 123–146. doi:10.1558/jircd.v7i1.2192
- Lenden, J. M., & Flipsen, P. (2007). Prosody and voice characteristics of children with cochlear implants. *Journal of Communication Disorders*, 40(1), 66–81. doi:10.1016/j.jcomdis.2006.04.004
- Linebaugh, C. E., & Wolfe, V. E. (1984). Relationships between articulation rate, intelligibility, and naturalness in spastic and ataxic speakers. In M. R. McNeil, J. C. Rosenbek, & A. E. Aronson (Eds.), *The dysarthrias: Physiology, acoustics, perception, management* (pp. 197–205). San Diego, CA: College-Hill Press.
- Manning, W. H. (2001). *Clinical decision making in fluency disorders* (2nd ed.). San Diego, CA: Singular Publishing Group.
- Martin, R. R., Haroldson, S. K., & Triden, K. A. (1984). Stuttering and speech naturalness. *Journal of Speech and Hearing Disorders*, 49(1), 53–58.

- Marzinzik, M. (2000). *Noise reduction schemes for digital hearing aids and their use for the hearing impaired*. Aachen, Germany: Shaker Verlag.
- McLeod, S., & Searl, J. (2006). Adaptation to an electropalatograph palate: Acoustic, impressionistic, and perceptual data. *American Journal of Speech-Language Pathology*, 15(2), 192–206. doi:10.1044/1058-0360(2006/018)
- McNeil, M. R., Liss, J. M., Tseng, C., & Kent, R. D. (1990). Effects of speech rate on the absolute and relative timing of apraxic and conduction aphasic sentence production. *Brain and Language*, 38(1), 135–158.
- Metz, D. E., Schiavetti, N., & Sacco, P. R. (1990). Acoustic and psychophysical dimensions of the perceived speech naturalness of nonstutterers and posttreatment stutterers. *Journal of Speech and Hearing Disorders*, 55(3), 516–525.
- Odell, K., McNeil, M. R., Rosenbek, J. C., & Hunter, L. (1990). Perceptual characteristics of consonant production by apraxic speakers. *Journal of Speech and Hearing Disorders*, 55, 345–359.
- Onslow, M., Adams, R., & Ingham, R. (1992). Reliability of speech naturalness ratings of stuttered speech during treatment. *Journal of Speech & Hearing Research*, 35(5), 994–1001. doi:10.1044/jshr.3505.994
- Onslow, M., Hayes, B., Hutchins, L., & Newman, D. (1992). Speech naturalness and prolonged-speech treatments for stuttering. *Journal of Speech, Language, and Hearing Research*, 35, 274–282. doi:10.1044/jshr.3502.274
- Onslow, M., & Ingham, R. J. (1987). Speech quality measurement and the management of stuttering. *Journal of Speech and Hearing Disorders*, 52(1), 2–17.
- Osberger, M. J. (1987). Training effects on vowel production by two profoundly hearing-impaired speakers. *Journal of Speech and Hearing Research*, 30, 241–251.
- Parkhurst, B. G., & Levitt, H. (1978). The effect of selected prosodic errors on the intelligibility of deaf speech. *Journal of Communication Disorders*, 11(2–3), 249–256.
- Ratcliff, A., Coughlin, S., & Lehman, M. (2002). Factors influencing ratings of speech naturalness in augmentative and alternative communication. *AAC: Augmentative and Alternative Communication*, 18(1), 11–19.
- Runyan, C. M., & Adams, M. R. (1978). Perceptual study of the speech of “successfully therapeutized” stutterers. *Journal of Fluency Disorders*, 3(1), 25–39. doi:10.1016/0094-730X(78)90004-9
- Runyan, C. M., & Adams, M. R. (1979). Unsophisticated judges’ perceptual evaluations of the speech of “successfully treated” stutterers. *Journal of Fluency Disorders*, 4(1), 29–38. doi:10.1016/0094-730X(79)90029-9
- Runyan, C. M., Hames, P. E., & Prosek, R. A. (1982). A perceptual comparison between paired stimulus and single stimulus methods of presentation of the fluent utterances of stutterers. *Journal of Fluency Disorders*, 7(1), 71–77. doi:10.1016/0094-730X(82)90040-7
- Ryalls, J. H. (1981). Motor aphasia: Acoustic correlates of phonetic disintegration in vowels. *Neuropsychologia*, 19(3), 365–384.
- Sacco, P. R., Metz, D. E., & Schiavetti, N. (1992). Speech naturalness of nonstutterers and treated stutterers: Acoustical correlates.
- Schiavetti, N., Whitehead, R., Whitehead, B., & Metz, D. (1998). Effect of fingerspelling task on temporal characteristics and perceived naturalness of speech in simultaneous communication. *Journal of Speech, Language & Hearing Research*, 41(1), 5–17. doi:10.1044/jslhr.4101.05
- Shikani, A. H., & Dietrich-Burns, K. (2012). Comparison of speech parameters and olfaction using different tracheotomy speaking valves. *International Forum of Allergy & Rhinology*, 2(4), 348–353. doi:10.1002/alr.21018
- Simmons, N. (1983). Acoustic analysis of ataxic dysarthria: An approach to monitoring treatment. In W. Berry (Ed.), *Clinical dysarthria* (pp. 283–294). Austin, TX: ProEd.
- Southwood, M. H., & Weismer, G. (1993). Listener judgments of the bizarreness, acceptability, naturalness, and normalcy of the dysarthria associated with amyotrophic lateral sclerosis. *Journal of Medical Speech-language Pathology*, 1(3), 151–161.

- Spencer, K., Morgan, K., & Blond, E. (2009). Dopaminergic medication effects on the speech of individuals with Parkinson's disease. *Journal of Medical Speech-language Pathology*, 17(3), 125–144.
- Stocks, R., Dacakis, G., Phyland, D., & Rose, M. (2009). The effect of smooth speech on the speech production of an individual with ataxia dysarthria. *Brain Injury*, 23(10), 820–829. doi:10.1080/02699050902997888
- Strand, E. A., & McNeil, M. R. (1996). Effect of length and linguistic complexity on temporal acoustic measures in apraxia of speech. *Journal of Speech, Language and Hearing Research*, 39, 1018–1033. doi:10.1044/jshr.3905.1018
- Tamplin, J. (2008). A pilot study into the effect of vocal exercises and singing on dysarthric speech. *NeuroRehabilitation*, 23(3), 207–216.
- Tjaden, K. (2000). Exploration of a treatment technique for prosodic disturbance following stroke. *Clinical Linguistics & Phonetics*, 14(8), 619–641. doi:10.1080/026992000750048143
- Tse, A. C., Wong, A. W., Ma, E. P., Whitehill, T. L., & Masters, R. S. (2013). Influence of analogy instruction for pitch variation on perceptual ratings of other speech parameters. *Journal of Speech, Language, and Hearing Research*, 56(3), 906–912. doi:10.1044/1092-4388(2012/12-0051)
- Wertz, R. T., LaPointe, L. L., & Rosenbek, J. C. (1984). *Apraxia of speech in adults: The disorders and its management*. Orlando, FL: Grune and Stratton.
- Whitehill, T. L. (2002). Assessing intelligibility in speakers with cleft palate: A critical review of the literature. *Cleft Palate-Craniofacial Journal*, 39(1), 50–58. doi:10.1597/1545-1569_2002_039_0050_aaiiswc_2.0.co_2
- Whitehill, T. L., & Chun, J. C. (2002). Intelligibility and acceptability in speakers with cleft palate. In F. Windsor, M. L. Kelly, & N. Hewlett (Eds.), *Investigations in clinical phonetics and linguistics* (pp. 405–415). Mahwah, NJ: Lawrence Erlbaum Associates.
- Witzel, M. A. (1995). Communicative impairment associated with clefting. In R. J. Shprintzen & J. Bardach (Eds.), *Cleft palate speech management: a multidisciplinary approach* (pp. 137–166). St. Louis, MO: Mosby.
- Wyatt, R., Sell, D., Russell, J., Harding, A., Harland, K., & Albery, E. (1996). Cleft palate speech dissected: A review of current knowledge and analysis. *British Journal of Plastic Surgery*, 49, 143–149. doi:10.1016/S0007-1226(96)90216-7
- Yorkston, K. M., Beukelman, D. R., Minifie, F. D., & Sapir, S. (1984). Assessment of stress patterning. In M. R. McNeil, J. C. Rosenbek, & A. E. Aronson (Eds.), *The dysarthrias: Physiology, acoustics, perception, management* (pp. 197–205). San Diego, CA: College-Hill Press.
- Yorkston, K. M., Beukelman, D. R., Strand, E. A., & Bell, K. R. (1999). *Management of motor speech disorders in children and adults* (2nd ed.). Austin, TX: Pro-Ed.
- Yorkston, K. M., Beukelman, D. R., Strand, E. A., & Hakel, M. (2010). *Management of motor speech disorders in children and adults* (3rd ed.). Austin, TX: Pro-Ed.
- Yorkston, K. M., Hammen, V. L., Beukelman, D. R., & Traynor, C. D. (1990). The effect of rate control on the intelligibility and naturalness of dysarthric speech. *Journal of Speech and Hearing Disorders*, 55, 550–560.
- Youmans, G., Youmans, S. R., & Hancock, A. B. (2011). Script training treatment for adults with apraxia of speech. *American Journal of Speech-Language Pathology*, 20(1), 23–37. doi:10.1044/1058-0360(2010/09-0085)