Research

Comparisons of Audio and Audiovisual Measures of Stuttering Frequency and Severity in Preschool-Age Children

Isabelle Rousseau
Mark Onslow
Ann Packman
Australian Stuttering Research Centre, The University of Sydney

Mark Jones
Queensland Clinical Trials Centre, University of Queensland, Australia

Purpose: To determine whether measures of stuttering frequency and measures of overall stuttering severity in preschoolers differ when made from audio-only recordings compared with audiovisual recordings.
Method: Four blinded speech-language pathologists who had extensive experience with preschoolers who stutter measured stuttering frequency and rated overall severity from audio-only and audiovisual recordings of 36 preschool children who were stuttering. Stuttering frequency (percentage of syllables stuttered [%SS]) was based on counts of perceptually unambiguous stutterings, made in real time, and overall severity was measured using a 9-point rating scale.
Results: Stuttering frequency was statistically significantly lower by around 20% when made from audio-only recordings. This was found to be directly attributable to differences in the counts of stuttered syllables, rather than to differences in the total numbers of syllables spoken. No significant differences were found between recording modalities for the ratings of overall severity. Correlations between %SS scores in the 2 modalities and severity rating scores in the 2 modalities were high, indicating that observers agreed on data trends across speech samples.
Conclusions: Measures of %SS made from audio-only recordings may underestimate stuttering frequency in preschoolers. Although audio-only %SS measures may underestimate stuttering frequency at the start of a clinical trial to a clinically significant extent, posttreatment scores at or below 1.0%SS are likely to underestimate by 0.2%SS or less, which is clinically insignificant.

Key Words: stuttering severity, stutter count, stuttered syllables, audiovisual measures

Stutter count measures are now widely used in stuttering research. In clinical trials, outcome measures based on stutter counts are typically collected with blinded, independent observations of naturalistic, non-treatment-related recordings. Speech-language pathologists (SLPs) also use stutter count measures to assist in clinical decision making and to measure the outcomes of their interventions. One widely used stuttering measure is percentage of syllables stuttered (%SS). This is a measure of the frequency with which syllables are perceived to be stuttered.

Another stuttering measure used by researchers and SLPs is severity rating (SR). This procedure is not based on counting stuttered events, but conveys listener perceptions of the overall severity of stuttering, typically using 7- or 9-point scales. An exception to this is the 10-point clinical scale used by parents of preschool children who are participating in the Lidcombe Program of Early Stuttering Intervention (Onslow, Packman, & Harrison, 2003).

The authors and a colleague have developed a behavioral system for describing stuttering, known as the Lidcombe Behavioral Data Language (LBDL; Teesson, Packman, & Onslow, 2003). The LBDL describes stuttering according to observable audible and visible movements of the speech production organs. As Teesson et al. discuss, previous descriptive systems were based largely on theoretical positions on the nature of stuttering and are not operational. It is important to note that the LBDL does not provide a definition of stuttering but rather categorizes speech behavior *that has already*

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been judged to be stuttering. There are three categories of stuttering behavior: *repeated movements* (syllable repetition, part-syllable repetition, multisyllable unit repetition), *fixed postures* of the speech production organs (with and without audible airflow), and *superfluous behaviors* (verbal and nonverbal; for further explanation, see Teesson et al., 2003). All three categories have visual components, but this is especially the case for the latter two. In *fixed postures,* speech ceases as the speech organs are held in an articulatory posture. This may be accompanied by audible airflow, such as in "ssssssometimes," but typically speech ceases completely, without audible airflow. Without access to visual information, this could be mistaken for normal pausing. *Superfluous nonverbal behaviors* typically consist of grimacing, excessive eye movements, tongue protrusion, and extraneous movements of the limbs and extremities that, again, are not detectible without access to visual information. These non-audible stuttering behaviors, then, may be problematic for measurement that is not done live. This raises the question: Should measures of stuttering be based on audiovisual recordings, to reflect the full picture, or are audio-only recordings sufficient?

Logistically, it is far simpler to use audio-only recordings, particularly in clinical trials, where socially valid outcome measures need to be made from speech samples in naturalistic speaking situations. It is a simple procedure for participants or parents to audio record speech samples in these situations. Even more conveniently, recordings of naturalistic speech samples can be obtained over a telephone line (Block, Onslow, Packman, Gray, & Dacakis, 2005; Boberg & Kully, 1994). However, it is intuitive that audio-only assessments of stuttering may underestimate stuttering severity because observers do not have access to visual stuttering behaviors.

A review of the literature indicates, however, that the use of video recordings in collecting outcomes in clinical trials of stuttering treatments is not routine. For the present purposes, a clinical trial can be characterized as a treatment trial that incorporates (a) evaluation of an entire treatment (not just part thereof), (b) outcomes measured from recordings (for assessment of reliability and validity), and (c) outcomes measured before treatment and at least 6 months after treatment. Using this definition, a review of clinical trials in stuttering since 1965 indicates the following: (a) for adults, only seven trials have incorporated stuttering outcome measures made from video recordings (Boberg, 1981; Boberg & Kully, 1985; De Nil & Kroll, 1995; Huinck et al., 2006; Langevin & Boberg, 1993; Mallard & Kelley, 1982; Schwartz & Webster, 1977); (b) for adolescents, only five have incorporated video recordings (Boberg, 1981; Bray & Kehle, 1998, 2001; Hewat, Onslow, Packman, & O'Brian, 2006; Langevin & Boberg, 1993); (c) for children, only six have incorporated video recordings (Block, Onslow, Roberts, & White, 2004; Bray & Kehle, 1998; Budd, Madison, Itzkowitz, George, & Price, 1986; Druce, Debney, & Byrt, 1997; Kully & Boberg, 1991; Madison, Budd, & Itzkowitz, 1986); and (d) for preschool children (younger than 6 years), only three have incorporated video recordings (Elliott, Miltenberger, Rapp, Long, & McDonald, 1998; Kully & Boberg, 1991; Rousseau, Packman, Onslow, Harrison, & Jones, 2007).

The notable absence of video recordings in clinical trials research with preschoolers is particularly pertinent because it is critical that the severity of stuttering is not underestimated at a time when the disorder is most responsive to treatment. The validity of stuttering measures based on audio-only recordings may be additionally threatened in preschoolers by the fact that young children are sometimes difficult to understand and syllable boundaries may be blurred. Also, it can occasionally be difficult to establish whether an individual speech disruption is a stutter or a normal disfluency. Johnson and Associates (1959) used data language to demonstrate an apparent overlap in terms of speech behaviors between stuttering and nonstuttering preschoolers, and many subsequent reports have replicated this finding, using an identical or similar data language (e.g., Adams, 1977, 1980; Perkins, Kent, & Curlee, 1990). This effect was described theoretically with Bloodstein's continuity hypothesis, which suggests that stuttering moments and moments of normal disfluency lie on a continuum (Bloodstein, 1970). In this hypothesis, then, those speech events that lie between normal disfluency and stuttering are ambiguous. This ambiguity may be exacerbated when visual information is not available.

SLPs usually have little difficulty determining clinically whether a preschool child is stuttering and requires treatment (Onslow, Packman, & Payne, 2007). Such a decision is typically made after observing the child and in consultation with the parent. However, problems may arise when SLPs request that parents record their preschool children beyond the clinic, in order to assess the extent of a child's stuttering in the real world. The issue of whether video recordings are necessary is particularly salient given recent interest in telehealth adaptations of stuttering treatments for preschool children. In the telehealth version of the Lidcombe Program, for example, the parent and child do not attend the clinic and the parent-delivered treatment is directed and monitored by the SLP from a distance (Harrison, Wilson, & Onslow, 1999; Lewis, Packman, Onslow, Simpson, & Jones, 2008; Wilson, Onslow, & Lincoln, 2004). Typically, the parent regularly sends recordings of the child's speech to the SLP, and the SLP needs to know whether audio-only recordings are sufficient to validly establish the child's progress and to inform decisions about when to terminate treatment, or whether audiovisual recordings are also needed.

Considering its importance, there has been surprisingly little research into comparing stuttering measures made from audiovisual and audio-only recordings. Panico, Healey, Brouwer, and Susca (2005) reported that audio or audiovisual presentation mode did not influence negative listener perceptions of stuttering speakers. Wenker, Wegener, and Hart (1996) reported that more favorable personality traits were elicited from live presentations of stuttering speakers than from audio recordings. Martin and Haroldson (1992) found that there were no differences in stuttering SRs on a 9-point scale between audio and video mode. However, they also reported that speech was judged to be more unnatural in video mode compared with audio-only mode, when measured on a 9-point speech naturalness scale. Williams, Wark, and Minifie (1963) also compared audio and audiovisual modes and reported that there were no differences in stuttering severity measures, using a 9-point scale, between audio and audiovisual presentation of 17.5-s speech samples.

In short, there is evidence that mode of assessment (audio-only, audiovisual) does not influence measures of stuttering severity. However, this research has all been conducted with adults. The research question driving the present study, then, was as follows: For preschool children who stutter, is there a difference between measures made from audio-only and audiovisual recordings, for both stuttering frequency and stuttering severity?

Method

Participants

Participants were 36 children younger than 6 years who had presented at a metropolitan public speech clinic in Sydney, Australia, for treatment for stuttering. All participants met the following inclusion criteria: (a) age 3–6 years, (b) English the main language spoken at home, (c) onset of stuttering more than 3 months previously, and (d) no treatment for stuttering in the previous 6 weeks. Twenty-six (72%) were boys, and 28 (78%) had a reported family history of stuttering. Mean age at time of recording was 46 months, and the children had been stuttering for an average period of 12 months. All children had been brought to the clinic by parents who were concerned about the child's stuttering, and the children were subsequently confirmed to be stuttering by two experienced SLPs.

Recording and Measurement Procedures

Each child was videotape-recorded in the clinic interacting with a parent and an SLP, while playing with a standard set of toys. The parent and child were seated next to each other at a table, and the head and shoulders of the child were recorded and were always visible. On the rare occasion that a child stood and moved around, the recording was stopped and restarted when the child sat down. The child's speech was recorded using a lapel microphone located either on the child or, on occasions when the child would not tolerate this, on the parent. Arc lighting was used for the recordings.

The audio-only samples were constructed by dubbing the audio track of the video recordings onto audiotape. Audio samples were presented through a Sony Professional Walkman WM-D6C tape recorder and Sennheiser HD 500 headphones. Audiovisual samples were recorded on DVDs and were presented through a DVD player connected to a television monitor and the same headphones.

The 36 speech samples, each of approximately 10 min duration, were randomly presented blind to four different SLPs who were independent of the study. Each had at least 5 years' experience measuring stuttering frequency (%SS) and stuttering severity in preschoolers, in clinical and research contexts. All used identical methods for making the two measures. Each made the measures from the 36 samples, in their entirety, as follows: 9 in *audio* mode with *%SS,* 9 in *audiovisual* mode with *%SS,* 9 in *audio* mode with *SRs,* and 9 in *audiovisual* mode with *SRs.*

The order of the four conditions was different for each observer. A total of 144 scores were obtained: 36 samples × two speech measures (%SS/SR) × two assessment modes (audio/audiovisual). This resulted in each sample having a pair of %SS scores (one made in audio-only mode and one made in audiovisual mode) and a pair of SRs (one made in audio-only mode and one made in audiovisual mode).

The %SS measures were made in real time (recordings were not paused or replayed) with a button-press counting device, with the observer pressing one button for each syllable judged to be unambiguously stuttered and another button for every other syllable. At the end of each sample, the device automatically calculated and displayed %SS, along with the number of stutters and the total number of syllables spoken. Observers recorded these data on a form. SRs for each sample were made using a 9-point scale, with 1 = *no stuttering* and 9 = *extremely severe stuttering*. No exemplars of stuttering severity were provided. Observers recorded SRs on a form at the conclusion of each sample.

Statistical Considerations

Analysis was performed using SAS Version for Windows 9.1. Analysis of variance (ANOVA) was used to compare stuttering measures based on audio-only samples with stuttering severity based on audiovisual samples. The effects of subject and rater were taken into account in the models to ensure as far as possible that effects were due to differences in modality rather than observers. Separate models were used for SR and %SS. Due to moderate positive skew, the %SS data were log transformed prior to analysis. Back transformation of the coefficients obtained from this model allowed proportional differences in stuttering measures to be estimated. Similar models were used for the number of stutters and number of syllables spoken. Two-sided p values of less than .05 were considered statistically significant.

Spearman rank correlations were performed for both %SS and SR, between the two modalities, to establish the reliability of the data trends. Nonparametric correlation was used because the data were not normally distributed, and because the nonparametric statistic is not affected by the systematic, multiplicative bias found for %SS.

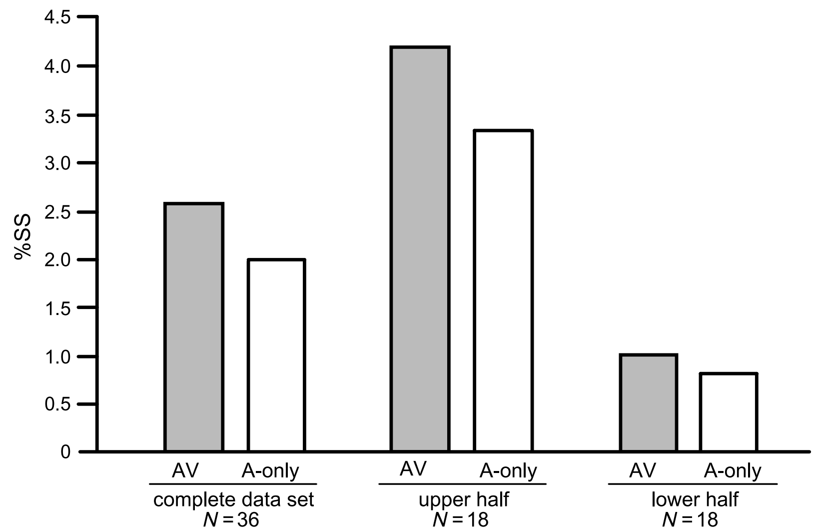
Results

Audio-Only and Audiovisual Comparison of %SS

Scores for %SS were lower in audio-only mode than in audiovisual mode. The mean audio-only %SS was 2.0 (SD = 1.85, range = 7.6–0.2), and the mean audiovisual %SS was 2.6 (SD = 2.81, range = 13.9–0.2). The means are shown in Figure 1. The raw data suggested that discrepancies were greater for higher %SS scores than for lower ones. To investigate this, the range of audiovisual %SS scores was divided into the upper 18 and the lower 18, and comparisons are shown in Figure 1.

ANOVA resulted in a statistically significant difference in %SS between audio-only mode and audiovisual mode (p = .014). The %SS scores based on audiovisual samples were 21% higher than those based on audio-only samples

FIGURE 1. Stuttering frequency (percentage of syllables stuttered [%SS]) for audiovisual (AV) and audio-only (A-only) modes for the entire data set (36 samples) and for the upper (18 samples) and lower (18 samples) halves of the data set.



(95% confidence interval = 5%–34%). Differences between audio-only and audiovisual measures for the upper and lower halves of the %SS distribution were not significant.

The mean number of stuttered syllables counted per sample for audio-only mode was 11.1 (SD = 10.59); for audiovisual mode, the mean was 13.6 (SD = 12.34). ANOVA indicated that this difference between modes was statistically significantly different ($p = .0072$). There were 19% more stuttered syllables identified using audiovisual samples compared with audio-only samples (95% confidence interval = 6%–30%). However, there was no significant difference in the total number of syllables spoken for audiovisual samples compared with audio-only samples ($p = .12$). This indicates that the difference in %SS was due to a difference in counts of stuttered syllables rather than to a difference in counts of total syllables spoken.

It is reasonable to suppose that audio-only measures of %SS were lower because observers did not have access to nonaudible features of stuttering. This would seem to be particularly so for those stuttering behaviors where the speech organs are fixed in articulatory postures, with no audible airflow. A detailed analysis was beyond the scope of this study; however, inspection of the data did not suggest that this was the case.

The Spearman rho for %SS between the two modalities was .82 ($p < .0001$). This indicates that observer agreement for trends in %SS scores for the two modalities was high, despite the fact that more stuttering was detected in the audiovisual mode.

Audio-Only and Audiovisual Comparison of SR

The mean SR for audio-only mode was 2.9 (SD = 1.33); for audiovisual mode, the mean was 2.9 (SD = 1.37). There was no difference in mean SR found using ANOVA ($p = .7$).

The Spearman rho for SR between the two modalities was .83 ($p < .0001$). As is the case for %SS, this indicates that observer agreement for trends in SRs for the two modalities was high.

Discussion

Given that stuttering behaviors are visible as well as audible, it is intuitive that stuttering measures based on audio-only recordings may underestimate stuttering severity. In the case of preschool children, the present results showed that this is the case for stuttering frequency (%SS) but not for stuttering severity (SR). Assessments based on audio recordings underestimated stuttering frequency by around 20%, when measures from audio-only and audiovisual modes were compared. The components of the %SS measure—number of syllables stuttered and total number of syllables spoken—were also analyzed. More stuttered syllables were identified in audiovisual mode, but there was no such difference for total syllables spoken. This indicates that the higher %SS scores in audiovisual mode can be attributed to more stuttering rather than to fewer syllables.

With an average underestimate of around 20% for audio-only samples, audio-only and audiovisual %SS scores were quite close at the lower end of the range of %SS range. This is an important observation, particularly for clinical research. While the differences in modality for the upper and lower halves of the distribution were not statistically significant, they should be regarded as having clinical significance. Although audio-only measures of stuttering may underestimate stuttering at the start of a clinical trial to a clinically significant extent, the risk of this is minimal in posttreatment outcome measures, when %SS scores are low. Audio-only posttreatment scores at or below 1.0%SS are likely to underestimate stuttering frequency by 0.2%SS or less, which is clinically insignificant.

One possible reason for the apparent underestimation of %SS in audio-only mode is that some disfluencies in early childhood are perceptually difficult to assign to "stuttered" and "nonstuttered" categories. These ambiguous disfluencies include all three LBDL behaviors: repeated movements, fixed postures, and superfluous behaviors. Interestingly, however, it did not appear that more visible-only behaviors were detected in audiovisual mode. In the opinion of the first author, who has had extensive experience measuring stuttering in preschoolers in both audio and audiovisual mode, the most likely reason for higher audiovisual %SS is that the visual image serves to increase the observer's attention. In audiovisual mode, the observer can attend to the communicative context, the child, the child's speech, and, of course, the child's stuttering. Thus, visual mode may allow for more ambiguous disfluencies to be judged to be stuttered. It would be interesting to pursue this in future research.

Of course, it is also possible to argue the opposite, namely that access to the visual image results in *overestimation* of stuttering frequency. However, audiovisual recordings are more similar to direct observation than audio-only recordings, and so must be considered the more valid measurement mode.

Interestingly, there were no differences in severity (SR), as rated on the 9-point scale, between the audio-only and audiovisual modes. In contrast to the many discrepant %SS scores between audio-only and audiovisual mode, only 1 of 36 pairs of SR scores differed by more than one scale value. A possible explanation for this is that the SR procedure does not require observers to make decisions about whether *individual* speech events are stuttered. Instead, an overall judgment of stuttering severity is elicited.

It is important to note that the recordings used in this study were made in a clinic, under ideal conditions, and not in naturalistic speaking situations. This procedure was used to ensure that recordings were of the highest quality and that measures were thus not confounded by differences in lighting, children disappearing out of view (as often happens in naturalistic contexts), extraneous household noise, and so on. This resulted in a trade-off: The video recordings were of excellent quality but were almost certainly not representative of video recordings that would be made by parents outside the clinic.

It is generally agreed that the frequency measure %SS provides the most informative measure of stuttering, because it is based on counts of stuttering events. The recommendation from the present findings, then, is that audiovisual measurement of %SS is best practice and provides a fundamental datum from naturalistic speaking situations in clinical and research applications. However, in many clinical and clinical research contexts, it is not possible for parents to obtain audiovisual recordings of preschool children. These include telehealth adaptations of treatments where the making of weekly audiovisual recordings can be impractical, and clinical trial applications where it is unlikely that the videotape recordings made by parents of their children in everyday speaking situations will be of sufficient quality to obtain valid measures. Hence, while it is recommended that %SS measures be based on audiovisual recordings whenever possible, it must be kept in mind that where audio-only recordings are the only option, they may result in stuttering frequency being underestimated. If SLPs are in doubt about the validity of a %SS measure made from an audio-only recording for a particular child, they could ask the parent to also video-record the child talking at home, perhaps lending the parent a video camera for that purpose, if required.

Of course, in clinical contexts, SLPs always have the option of having parents make one or more audio-only recordings in naturalistic contexts and then measuring stuttering severity with the 9-point scale. Providing there is reasonable agreement between the SLP and the parent (within ±1 scale point), this would provide a reliable indication of stuttering severity for an individual child, and a socially valid indication of the child's stuttering outside the clinic.

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Contact author: Mark Onslow, Australian Stuttering Research Centre, P.O. Box 170, Lidcombe, NSW 2141, Australia. E-mail: m.onslow@usyd.edu.au.