Exploring Feasibility and Effectiveness of Occasional Whispering in Adults who Stutter: Subjective and Objective Evaluations

Robert van de Vorst[1] *and Floris Tijmen van Vugt*[2,3,4,5]

[1] School of Communication Sciences and Disorders, McGill University, Montreal, Quebec, Canada

[2] Department of Psychology, University of Montreal, Montreal, Quebec, Canada

3 International Laboratory for Brain, Music and Sound Research BRAMS, Montreal, Quebec, Canada

[4] Centre for Research on Brain, Language and Music – CRBLM, Montreal, Quebec, Canada

[5] Haskins Laboratories, Yale University, New Haven, CI, USA

ABSTRACT

Stuttering is a challenging condition characterized by disfluencies which prior work has found to be momentarily improved during whispering. The present study explores the clinical potential of whispering by examining whether the benefits of whispering remain stable with short-term use, extend to conversation tasks, and are feasible in daily life. Sixteen adult persons who stutter completed tests assessing the amount of stuttering for normal voiced speech and whispering during both conversation and reading-aloud tasks. Participants then used whispered communication in their daily lives and reported their subjective experiences. After three weeks, effectiveness tests were repeated. Stuttering severity was significantly lower for whispered speech (vs. typical speech) during a conversation task (50% reduction), although this effect was smaller than for the reading-aloud task (85% reduction). This reduction remained present and comparable in magnitude after three weeks of approximately 5 to 10 minutes of daily whispering. Participants subjectively indicated positive experiences with respect to the effects of whispering on fluency and reported that whispering helped reduce stuttering-related anxiety. However, four participants (25%) reported negative voice side effects (e.g., hoarseness, vocal-fold strain), associated with regular whispering. Occasional use of whispering can effectively reduce stuttering and related behaviors during both reading-aloud and conversational speech. This result paves the way for future technological applications that convert whispered speech into natural sounding speech in real-time.

OPEN DATA

KEYWORDS

stuttering
whispering
therapeutic benefits
short-term stability
subjective evaluation
feasibility

INTRODUCTION

Developmental stuttering, a childhood-onset fluency disorder, may have profound negative consequences once it persists into adolescence and adulthood. Dysfluency symptoms in persons who stutter (PWS) may be exacerbated under certain circumstances such as phone calls or speaking under time pressure (Silverman, 1997). It remains a challenge to provide effective, long-term support for PWS in those situations. Whispering has previously been shown to yield immediate symptom improvements (Ingham et al., 2009). However, little data is available about its effects during conversational speech and real-life situations or on whether its effects are durable over time. Recent technological advances may make it possible to use whispering during limited cases of daily communication such as phone calls. Prior to such implementations, it is necessary to understand whether the effects of whispering remain stable over at least short periods of time, are not harmful, and are subjectively perceived as helpful. The current study examined all of these questions.

Complete recovery of persistent stuttering in adolescents and adults is rare (Bloodstein et al., 2021; Kell et al., 2018; Tichenor & Yaruss, 2020). Therapeutic support offered to PWS can be a flexible combination of fostering greater acceptance of the condition and minimizing the symptoms (dysfluencies). Fostering acceptance involves reframing stuttering not as a flaw that needs repairing but as a condition deserving respect and consideration in its own right (Gerlach & Constantino, 2022; Watermeyer & Kathard, 2016). A parallel, complementary approach explores conditions that may reduce stuttering. The current study focused on the latter approach.

Several conditions produce high levels of fluency almost instantaneously, albeit temporarily. These fluency-inducing conditions include speaking along with a metronome, speaking during a loud broad-band

Corresponding author: Robert van de Vorst, School of Communication Sciences and Disorders, McGill University, Montreal, Quebec, Canada.

Email: robertvandevorst@gmail.com

noise sound (masking), changing the phonation intervals, reading in unison with another speaker (chorus reading), speaking with an accent, singing, or acting (Adams & Ramig, 1980; Andrews et al., 1982; Barber, 1939, 1940; Block et al., 2004; Colcord & Adams, 1979; Commodore & Cooper, 1978; Goldiamond, 1965; Ingham et al., 2009; Johnson & Rosen, 1937; Kalinowski et al., 2000; Martin & Haroldson, 1979; for a review, see Baxter et al., 2016).

Although each of these conditions is promising, it remains challenging to apply them in real life. First of all, the beneficial effects tend to be restricted to when participants use the fluency-inducing condition. Once participants return to their habitual manner of speaking, the stuttering often reemerges. This means that to be useful, the condition has to be potentially applied during a substantial portion of the time in daily life that people speak, which is challenging methodologically (e.g., presenting broad-band noise during daily life, speaking in unison with another person during a real-life conversation). Even when such challenges would be overcome, a deeper issue emerges: the therapeutic benefit of an intervention is often reduced with such prolonged use. This has been studied in the case of altered auditory feedback (AAF), which involves altering the way that a person hears their own speech, for example, by delaying it or modifying frequency contents. Although AAF tends to be effective at the outset, the response over periods of prolonged use is more variable. This variability in effectiveness depends mostly on follow-up length, task, and test setting (Armson, et al., 2006; O'Donnell, et al., 2008; Pollard, et al., 2009; Stuart, et al., 2004; Stuart, et al., 2006). Some studies have reported that the initial fluency benefits wear off over time (Ingham et al., 1997; O'Donnell et al., 2008) and the debate on effectiveness continues (Foundas et al., 2013; Pollard et al., 2009; Saltuklaroglu et al., 2010). Data on the clinical effectiveness of fluency-inducing conditions other than AAF remains sparse (Baxter et al., 2016). In sum, while effective clinical implements exist, there are ongoing challenges to implementation and, as a result, it remains worthwhile to explore viable alternatives as complements or add-ons.

As the development and the use of digital applications increases, real-life implementations for other fluency-inducing conditions such as whispering, which we focused on in the current study, may become available. Indeed, algorithms are becoming increasingly sophisticated in converting whispered speech into voiced speech in real time (Ahmadi et al., 2008; Janke et al., 2014; Konno et al., 2016; Perrotin & McLoughlin, 2020). This technology could, at least in principle, be embedded in a smartphone for use during phone or video-calls, which are situations that are known to be challenging to PWS (Georgieva, 1994; Silverman, 1997). This could conceivably enable PWS to whisper into their phone while their conversation partner hears, in real-time, a normal speech conversion. Apart from the technological challenges of such an idea (such as reducing processing delays), it raises questions whether such technology would be effective in real-life settings and whether its effect would be stable over time. It is necessary to better understand whispering and how it could be applied in the lives of PWS.

The therapeutic potential for whispering is closely tied to vocal physiology. During whispered speech, contrary to ordinary voiced speech, vocal fold vibration is minimal or even completely absent (Monoson & Zemlin, 1984). As initiation and (and termination) of voiced speech segments is often a core problem in stuttering (Chang & Guenther, 2020; Cullinan & Springer, 1980; Kikuchi et al., 2018), whispering can temporarily but often drastically reduce stuttering symptoms (Bruce & Adams, 1978; Bloodstein, 1950; Johnson & Rosen, 1937; Perkins et al., 1976; Rami et al., 2005). Experimental studies have shown 60-80% dysfluency reduction when using whispered speech relative to normal speech (Ingham et al., 2009; Ingham et al., 2012). However, real-life use of whispering is hampered by obvious limitations. Whispered speech tends to be quieter, leading to problems of intelligibility (Hendrickson & Ernest, 2022). Additionally, whispering will likely be socially perceived as unusual or awkward, making it impractical. Potentially, these problems can be overcome in the context of phone or video conversations if an app would convert the whispered speech to voiced speech in real-time. In sum, whispering, at least in the lab, can effectively reduce stuttering, and although impractical on its own, may be promising in specific contexts when technologically supported.

Several limitations currently stand in the way of using technology-supported whispering as a component of stuttering therapy. First, little is known about the effects of whispering during conversational speech and in real-life. Prior studies that found effects of whispering on stuttering used tasks where subjects read written text aloud, but did not test whether such effects hold during conversation. This question is not trivial since the effectiveness of other fluency-inducing conditions differs considerably depending on the task and context (see Armson et al., 2006; Lincoln et al., 2006; Pollard et al., 2009), with most of them showing greater benefits for reading compared to conversation (Foundas et al., 2013; Ingham et al., 1997; Pollard et al., 2009; Unger et al., 2012). In the current study, we asked whether the fluency benefits of whispering are also present during conversation. We hypothesized that whispering would be beneficial during conversation too, but like with other fluency-inducing conditions, possibly less so than during reading. To our knowledge, this has not been tested before.

A second challenge to whispering as a clinical tool is to understand whether it is safe. There is some indication that, at least for some individuals, frequent whispering may put additional strain on the vocal cords (Rubin et al., 2006; Tsunoda et al., 1994). In fact, several authors have argued that whispering should not be generally recommended as a substitute for spoken communication, for example, when experiencing voice-related problems (House & Fisher, 2017; Rosen et al., 1998). However, few studies have systematically and empirically investigated the risks of whispering, nor are data on the effects of long-term (or even mid-term) and frequent whispering in healthy populations available. Thus, in order to validate whispering as a tool for addressing stuttering, data about real-life usage experience beyond laboratory settings is needed. The current study addressed this gap by collecting subjective evaluations of people who were instructed to regularly use whispering in their daily lives over a short period of time.

A third challenge to whispering as a clinical tool is that it remains unclear whether it remains beneficial over time. Our question here is not whether benefits of whispered speech carry over to nonwhispered speech, but whether whispered speech itself remains consistently flu-

ent even after short-term use. To our knowledge, this has not been tested in the case of whispering, but in the case of other interventions (e.g., AAF) a portion of participants no longer experienced benefits after prolonged use (O'Donnell et al., 2008; for a review, see Baxter et al, 2016). Other fluency conditions may be more durable: Trotter et al. (1974) found that the beneficial effects of a metronome in reducing stuttering were maintained after several months of use. In sum, it is unclear whether the effects of whispering remain stable over time, which was tested in the current study. Note that the current study did not compare whispering to other fluency-inducing conditions such as AAF but tested whether whispering on its own is feasible for short-term, limited use.

The current preliminary study explored the potential of whispering in the lab and in real-life, combining subjective and objective measures. PWS were recruited and asked to whisper for short periods of time per day during three weeks. We tested stuttering during normally voiced and whispered speech before and after, not only during reading-aloud tasks but also during conversation. We also collected subjective measures of the effectiveness and potential harmful effects of whispering. Specifically, we examined the immediate effects of whispering on the frequency and severity of stuttering in conversation as opposed to reading aloud. We hypothesized that whispering would have beneficial effects in conversation as well, although perhaps to a lesser degree than during reading aloud. Secondly, we examined whether the beneficial effect of whispering would be reduced after short-term use. We hypothesized that whispering may show a smaller reduction in stuttering (relative to typical speech) after three weeks. Thirdly, we examined how participants subjectively experience using occasional whispered communication during daily life. Does it pose challenges in communication? We hypothesized that if there are harmful effects associated with frequent whispering (e.g., hoarseness, avoidance of stuttering, etc.) then participants would report this in a subjective questionnaire.

METHODS

Participants

Dutch- and English-speaking PWS were recruited through social media (Facebook, Twitter, etc.), stuttering related organizations and clinicians. Participants were asked to complete an entry survey (available in Dutch and English), which assessed their thoughts about whispering as a fluency-enhancing tool in real life and potential interest in a digital whispering-to-speech application. A total of 96 responses were collected. After screening according to inclusion/exclusion criteria (i.e., self-identifying as PWS, aged 18-70, being able to read/write/speak in either Dutch or English, no other clinical and/or speech disorders besides stuttering or cluttering), 89 responses were retained (36 females, 10.1% of the participants were 18-20 years old, 22.5% were 21-25, 20.2% were 26-35, 29.2% were 36-55, and 18.0% were 56 or older). We subsequently approached participants who provided consent to be contacted for further study (n = 22). We asked them to participate twice in a video call that involved an assessment of their overt stuttering (SSI-4; Riley, 2009) and to participate in a three-week trial which involved communicating using whispered communication for approximately 5 minutes several times a day (e.g., with a friend, family member, at work, etc.). At the end of the trial, participants completed a final evaluation about their experiences and were evaluated once more on the SSI-4. Participants were encouraged to report potential adverse events (e.g., hoarseness, negative stuttering experiences) via a logbook, which was also used to keep track of when and for how long participants engaged in whispered communication. Inclusion/exclusion criteria for the video call and three-week trial were identical to those for the initial questionnaire, with additional exclusion of participants who reported taking any medication that could cause significant psychological/physical side effects.

Eighteen PWS participated in the three-week trial. None of them were currently engaged in professional therapy. One participant dropped out due to lack of motivation to continue and another was not able to fulfill instructional requirements. Thus, a total of 16 PWS (6 females; age range = 19-58, M = 37.2, SD = 14.3) successfully completed the entire study. Participants received 50 Euro for their time and effort. This study was approved by the ethics committee of Leiden University Medical Center (LUMC) in the Netherlands and the study was conducted in accordance with the Declaration of Helsinki. All the patients provided prior written informed consent.

Procedure

STUTTERING SEVERITY INSTRUMENT (SSI-4).

PWS were assessed using the Stuttering Severity Instrument (SSI-4; Davidow & Scott, 2017; Riley, 2009) prior to the intervention (pre-test) and directly after (post-test). These sessions took place via video calls which were recorded. The SSI-4 assessment consisted of two tasks: reading aloud and spontaneous conversation. During the reading task, PWS read aloud samples from the SSI (or in case of Dutch participants, a text of similar difficulty) of approximately 200 syllables each. Subjects were instructed to speak at a comfortable rate and not to use any speech techniques or other strategies. Participants were further instructed to read the first text using a normal, voiced speech pattern and using whispered speech for the second text. Texts were counterbalanced across conditions and participants. The examiner first demonstrated the correct use of whispering: a soft and relaxed whisper. Subsequently, the examiner and participant engaged in two small conversations (one using normal, voiced speech and the other using whispered speech) of approximately 4 minutes each. Because the severity of stuttering might vary depending, among other things, on the person one communicates with (Bloodstein et al., 2021), a different examiner performed the post-test assessment. The order of tasks (reading-aloud/conversation) was counterbalanced across assessments and randomized across participants. The normal speech (baseline) condition always preceded the whispering condition, a design used in other studies as well (Foundas et al., 2013; Ingham et al., 2009). The data allowed measuring stuttering severity as the percentage of stuttered syllables (%SS), which was calculated separately for the reading-aloud and the conversation tasks.

Criteria for stutter-like dysfluencies were assumed in accordance with the SSI-4 guidelines. Normal dysfluencies (e.g., whole phrase repetitions, "ums" and "ers") were not counted. However, stutter-like blocks were included as they are typical for PWS and are not observed in fluent speakers. Further, the Stuttering Severity Index (SSI) was calculated and collapsed across conditions. This metric is calculated based on the %SS, but was analyzed separately in the Supplementary Materials since it essentially shows the same pattern of results.

WHISPERING DURING DAILY LIFE

After the pre-test assessment, participants implemented whispered communication in their daily life for three consecutive weeks. They were free to determine the length and frequency of their whispered communication. However, we requested them to target about 2-3 conversations of approximately 5 minutes per day. A restricted length of 5 minutes was chosen in order to minimize any vocal physiological problems as a result of whispering. Participants also reported daily with whom, how often, and for how long they communicated through whispering. In particular, they were encouraged to communicate any unwanted side-effects of whispering, such as voice-related problems, to the examiners. Depending on the complaint, we monitored and possibly corrected the participants' manner of whispering or instructed them to temporarily stop using whispered communication. This occurred with two participants, who, after consultation with the experimenters and a short break, continued with the study.

Data Analysis

Speech and whispered samples from the audio/video recordings were analyzed according to the SSI-4 protocols (Riley, 2009) by both examiners together. A random subset of the recordings (25%) was sent to an external certified speech-language pathologist with over 20 years of experience who rerated the recordings. To determine interrater reliability based on absolute agreement, we calculated the Intraclass Correlation Coefficient (ICC), which yielded an ICC of 0.93, with a 95% CI [0.83; 0.97], indicating excellent reliability. We tested whether fluency-enhancing effects of whispering were present in conversation as well as in the reading-aloud task using a three-way repeated-measures analysis of variance (ANOVA) with factors of time (pre/post), condition (normal speech/whispering), and task (reading/conversation), and with percentage of stuttered syllables (%SS) as the dependent variable. This also allowed us to assess whether the fluency effects of whispering wear off after time. However, a more sensitive measure of such wearing-off may be the overall SSI score, since it combines %SS across tasks. Therefore, we also calculated a repeated-measures ANOVA with factors of time (pre/post) and condition (normal speech/whispering), and with SSI score as the dependent variable, the results of which were comparable and included in Supplementary Materials. Assumptions for statistical tests used were met for the data: when groups being compared are equal, ANOVA is considered robust to violations of normality (Lunney, 1970). Follow-up tests were Bonferroni-corrected for a total of six follow-up contrasts, tested and reported as pbonf. For reference, we also report uncorrected p values (p_{uncorr}).

Further, to test for an absence of difference between the whispering effects before and after the three weeks, Bayesian t tests were used. The reason for using these tests is that they can assess evidence for or against the null hypothesis, whereas classical statistics testing (null-hypothesis significance testing) is designed to assess evidence against, not in favor of the null hypothesis (e.g., that there is no difference between conditions). Here, we used Bayesian t tests (Rouder et al., 2009), which involve calculating a Bayes Factor (expressed here as BF_{10}) that represents the relative evidence for the alternative versus the null hypothesis. The smaller this value, the more evidence in favor of the null hypothesis (in this case, absence of difference over time). Benchmark scores are: BF_{10} between 1 and 1/3 are considered to be weak, between 1/3 and 1/10 are considered substantial, and less than 1/10 are considered strong evidence in favor of the null hypothesis. The larger this value, the more evidence in favor of the alternative hypothesis (in this case, the presence of a difference over time), with benchmarks BF_{10} between 1 and 3 considered weak evidence and between 3 and 10 substantial (Jeffreys, 1961).

Clinically, it is important to find reductions in whispering effectiveness, if present. Given the short-term follow-up (3 weeks) and fairly limited use (approximately 5-10 minutes per day) in the current study, we employed analyses that are maximally sensitive to finding such differences. We hypothesized that if whispering effects wear off, those who used whispering more during the 3-week interval should show more stuttering severity during the post-test, which was assessed using Pearson correlations. Multiple correlations were computed, and hence, Bonferroni-corrected p values are reported for four tests (reading-aloud/conversation for both the absolute whisper effect and change in whispering effect).

As data checks, we verified whether stuttering severity during conversation correlated with severity during reading-aloud for all time points and conditions (Pearson correlations with Bonferroni-corrected p values for four comparisons) and whether stuttering severity during normal speech was correlated with whispering during both tasks and time points (Pearson correlations with Bonferroni-corrected p values for four comparisons).

χ^2 tests were conducted for categorical data in the subjective evaluations and Bonferroni-corrected for three comparisons.

RESULTS

Participants completed a stuttering assessment at two time points (pre- and post-test), separated by three weeks, during which they engaged in whispering in their daily lives. Afterwards, they completed a questionnaire assessing their subjective experiences.

Stuttering Severity Measurements

The main effect of condition (normal vs. whispering) was statistically significant, $F(1, 15) = 14.01$, $p < .002$, $\eta^2 = 0.48$, indicating that stuttering severity (%SS) was lower for whispering than for normal speech in both times and tasks (see Figure 1). The condition × task interaction was statistically significant, $F(1, 15) = 8.96$, $p < .009$, $\eta^2 = 0.37$. This indicated that although the benefit of whispering (i.e. stuttering being less during whispering relative to normal speech) was present in both the reading-

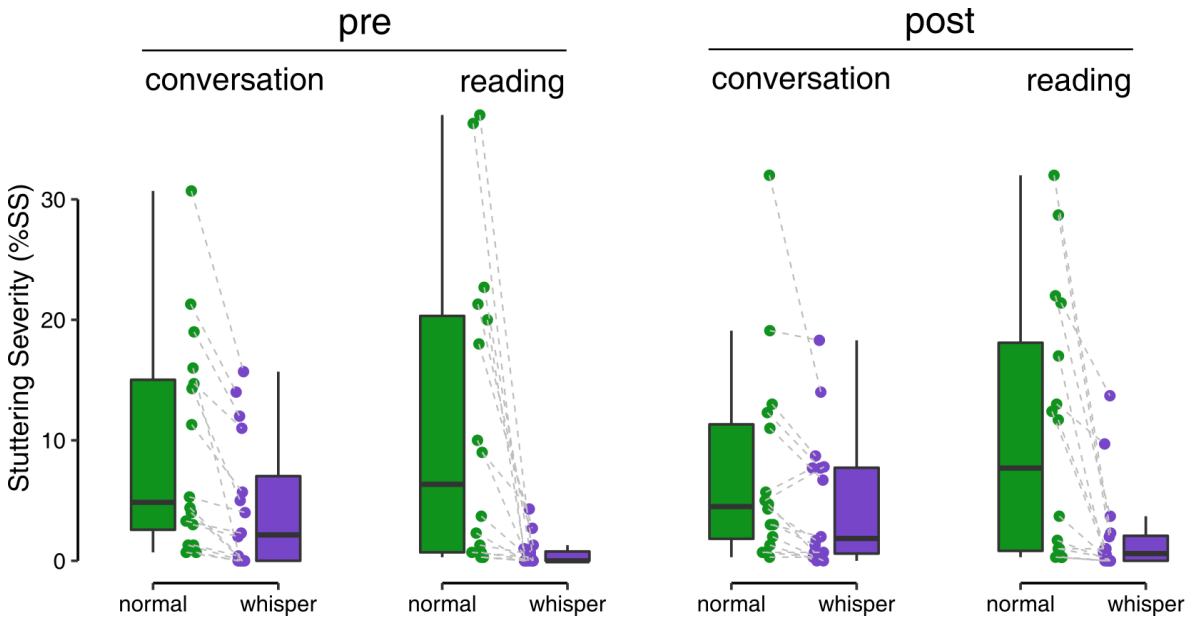

FIGURE 1.

Stuttering severity during normal and whispered speech at study onset (pre-test) and after 3 weeks (post-test). Dots indicate participants and boxplots indicate medians and quartiles. Gray dotted lines connect values for single participants. Stuttering severity is expressed as the percentage of stuttered syllables (%SS) during reading and conversation.

aloud, $t(15) = 3.56$, $p_{uncorr} = .003$, $p_{bonf} = .006$, and conversation tasks, $t(15) = 3.75$, $p_{uncorr} = .002$, $p_{bonf} = .004$, the size of this effect was somewhat smaller in the conversation ($M = 50\%$, $SD = 40\%$ reduction in severity, Cohen's $d = .32$) than in the reading condition ($M = 85\%$, $SD = 26\%$ reduction, Cohen's $d = .99$). Importantly, the effect of time was not statistically significant, $F(1, 15) = .32$, $p = .58$, nor were any of the interactions with time, all Fs $(1, 15) < 2.6$, $p > .12$, which indicates that there was no evidence for a reduction in the effect of whispering over time.

Although no statistically significant main effects of time were found, suggesting there was no reduction in effectiveness of whispering, we proceeded with the following, more stringent testing to maximize the chances of finding a reduction in whispering effectiveness if present. Restricting the analysis to the whispered condition only, we tested for differences in stuttering between pre and post time points. For stuttering severity during conversation, Bayesian paired t tests indicated substantial evidence in favor of the null hypothesis (i.e., that there is no difference over time), $BF_{10} = 0.28$. For stuttering severity during reading, a Bayesian paired t test, $BF_{10} = 2.83$, indicated weak evidence ("not worth more than a bare mention" according to the benchmarks in Jeffreys, 1961) for the alternative hypothesis (that there would be a difference). Thus, the present data provide evidence that whispering effectiveness is stable during conversation, whilst remaining inconclusive with respect to the stability of its effectiveness during reading.

As a further test for reductions in whispering effectiveness, we hypothesized that if whispering effects would be reduced over time, those who whispered more during the 3-week interval would show less effectiveness of whispering during the post testing. This was not true for either the reading-aloud (Pearson's $r = -.04$, $p_{uncorr} = .90$, $p_{bonf} = 1$) nor for the conversation tasks (Pearson's $r = -.20$, $p_{uncorr} = .47$, $p_{bonf} = 1$). Finally, we calculated the pre-to-post change in the effectiveness of whispering, that is, the stuttering severity during whispering minus during normal speech. This change was not correlated with the amount of whispering during the interval period, neither for the reading-aloud (Pearson's $r = .37$, $p_{uncorr} = .17$, $p_{bonf} = .68$) nor for the conversation tasks (Pearson's $r = .03$, $p_{uncorr} = .92$, $p_{bonf} = 1$).

As a data check, we verified that stuttering severity was mostly consistent across tasks: those who showed more stuttering during the conversation task also tended to show more stuttering during the reading-aloud, which was true during all time points and conditions (Pearson's $r > .81$, $p_{uncorr} < .0013$, $p_{bonf} = .005$), except for whispering during the pre-test, Pearson's $r = .31$, $p_{uncorr} = .25$, $p_{bonf} = .98$). Stuttering severity was also consistent between whispering and normal speech during the conversation task: overall stuttering was lower during whispering (see analysis above) but those who stuttered more during normal speech tended to also stutter more during whispering, during both the pre- and post-test, Pearson's $r > .86$, $p_{uncorr} < .0001$, $p_{bonf} < .0001$. This was not true for the reading-aloud task, Pearson's $r < .46$, $p_{uncorr} > .07$, $p_{bonf} = .29$.

Subjective Experience of Whispered Communication

During the 3-week interval between the pre- and post-test, participants reported an average of 28 whispered conversations, of which each conversation lasted an average of 7.5 min, yielding an average total of 199 whispered minutes per participant. Participants communicated mostly with their partners or close relatives. The frequency with which participants applied whispering to video/phone call or face-to-face interactions was not found to be statistically significantly different, paired t test, $t(15) = 0.61$, $p = .55$).

To assess participants' experiences using whispered communication, a custom-made questionnaire was administered after the second assessment (post-test) which contained 13 items rated on a 5-point Likert-scale (1 = *strongly disagree*; 5 = *strongly agree*, see Figure 2 and the Supplementary Materials for a full listing). Notably, 94.1% of participants agreed (or strongly agreed) that whispering improved their fluency and reduced their anxiety about stuttering. Subjective evaluations of broader impact on life were more mixed, with 47.1% agreeing (or strongly agreeing) and 29.4% feeling neutral as to whether whispering improved their communication overall. Nevertheless, 94.1% of participants were interested in whispering as one part of their stuttering therapy.

To simplify the presentation and statistical testing, we grouped the questions into three categories: speech fluency (Cronbach α = .48), quality of life (α = .65), and future use (α = .80). We further merged "strongly agree" and "agree" into a single ("agree") category for ease of analysis. We also merged "strongly disagree" and "disagree" into "disagree" (see Figure 2). For each of these three categories, we used χ^2 tests (Bonferroni-corrected for three comparisons) to investigate whether those who rated positive experiences outnumbered those who indicated neutral or negative experiences. Statistically significant main effects were found for all three categories, speech fluency: $\chi^2(2) = 141.34$, $p_{uncorr} < .001$, $p_{bonf} < .001$; quality of life: $\chi^2(2) = 8.76$, $p_{uncorr} = .013$, $p_{bonf} = .038$; future use: $\chi^2(2) = 79.41$, $p_{uncorr} < .001$, $p_{bonf} < .001$. This suggests that participants were largely positive with respect to the effects of whispering on speech fluency and whispering in general as a fluency tool, for example, in the context of digital applications or stuttering therapy.

A subset of participants reported negative experiences as well. Out of 16 participants who completed the questionnaire, four (24%) experienced some physical discomfort as a result of whispering. These participants were recommended to stop whispering for at least a few days or otherwise instructed to whisper very softly and with minimal tension in the vocal cords. One participant stopped whispering for five days and another participant for two days. Both participants indicated willingness to continue the study. The remaining two participants only reported minor harmful effects via the final questionnaire (which came after the 3-week intervention). During debriefing, both explained that these concerned minor temporary inconveniences that did not affect the overall experience of whispered communication.

DISCUSSION

This study investigated the potential of whispering to alleviate stuttering in realistic settings. Participants used whispering in daily conversations over a period of three weeks. Before and after, we measured stuttering severity comparing the effect of whispering relative to normal speech. This whispering effect was observed during reading-aloud and also, for the first time, during conversation, albeit somewhat smaller

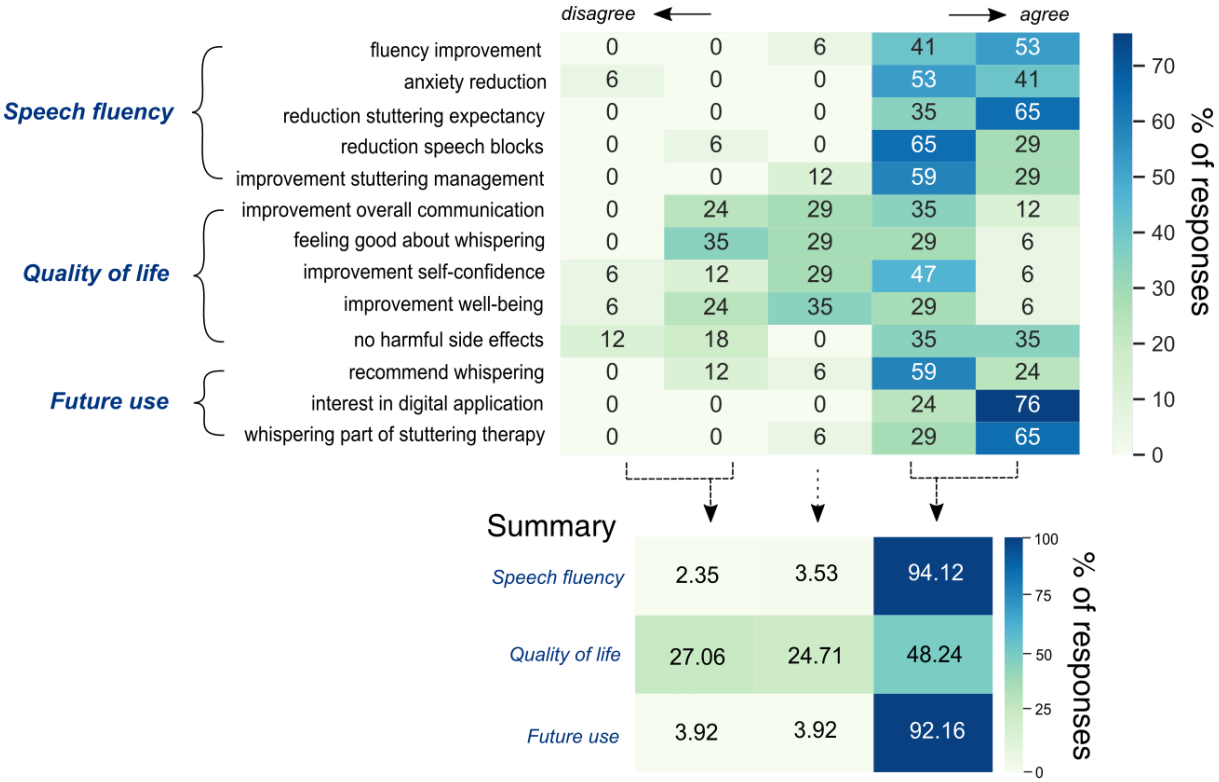

FIGURE 2.

Results of the questionnaire assessing subjective evaluations of the effects of whispering on communication. Top panel: frequencies per rating (1 = *strongly disagree*; 5 = *strongly agree*) and item. Lower panel: percentages per item category (speech fluency, quality of life, and future use) and rating category (disagree, neutral, and agree).

in magnitude. The beneficial effect of whispering remained after three weeks, suggesting there is little reduction in effectiveness with limited use in this short-term time frame. Subjectively, the majority of participants indicated positive experiences with regular whispering during daily life, particularly reductions in stuttering-related anxiety, although we did not find robust effects of whispering on quality of life. Some participants reported adverse side-effects of whispering.

Stuttering Reductions Across Tasks

We observed that whispering reduced stuttering not only during reading-aloud tasks, as shown previously (Ingham et al., 2009; Ingham et al, 2012; Johnson & Rosen, 1937), but also during spontaneous conversation. The whispering effect (i.e. reduction in stuttering while whispering) was somewhat smaller during conversation than during reading aloud. This is not surprising. First, conversational speech involves an additional number of processes compared to reading a written passage, including thought processes, selecting appropriate vocabulary, formulating a grammatically correct sentence, listening and responding to the conversational partner, and so forth. This additional layer of social, emotional, linguistic, and motor complexity may explain in general why moderate to severe stuttering almost exclusively occurs during (propositional) speech within a social context, as these processes may interfere with an already vulnerable motor system (Bosshardt, 2006; Smith & Weber, 2017). Indeed, other fluency-enhancing conditions, such as AAF, tend to have smaller effects during conversation (Foundas et al., 2013; Ingham et al., 1997; Pollard et al., 2009; Unger et al., 2012). To our knowledge, the current study is the first to show that whispering can be an effective tool for reducing the frequency and severity of stuttering during conversational speech.

Whispering Remains Effective During Short-Term Limited Use

The current results suggest that whispering-induced fluency gains remain stable during short-term limited use (3 weeks of 5-10 minutes daily whispering). In general, relapse after intervention (e.g., fluency shaping, stuttering modification) is a common experience amongst PWS (Craig, 1998; Craig & Hancock, 1995). Several studies that have explored the effects of other fluency-inducing conditions found that the initial fluency-enhancing effect appears to wear off with prolonged use (Ingham et al., 1997; O'Donnell et al., 2008). These studies generally used a longer duration and more intense use (e.g., 3 to 15 hours per day) than that used in our study (5 minutes per day), precluding direct comparisons between these fluency-inducing conditions and whispering.

The current findings show that the stuttering severity during whispering remains stable in the short term (i.e., 3 weeks), with exception of reading aloud, where whispering effectiveness may have been slightly reduced during the second assessment. The cumulative amount of whispered communication during the 3-week trial showed no correlation with stuttering severity or whispering effectiveness. This opens the road to investigating more long-term use of whispering to ask whether its effectiveness extends beyond the time frame investigated here. Note that the present dataset does not allow comparing whispering with other fluency-inducing interventions. These other interventions are typically tested with much greater exposure (up to 15 hours per day for extended periods of time, e.g., Ingham et al., 1997; O'Donnell et al., 2008). It remains questionable whether whispering would be feasible for such amounts of use and whether its effects would remain stable. Here, the purpose was to investigate whether whispering is viable for short-term, limited daily use.

Participants' Perceptions and Experiences

Individual subjective experiences were assessed with questionnaires designed for the purpose of the current study. Overall, participants reported that whispering decreased stuttering symptoms, reduced speech blocks (perhaps due to the reduced complexity of whispering compared to voiced speech, see Perkins et al., 1976), and helped manage stuttering better. In addition, nearly all participants reported a reduction in anxiety and expectancy of stuttering, which is potentially significant, because prior work found that exclusive use of fluency techniques did not decrease anxiety or negative thoughts (Blomgren, 2013). In fact, it is often suggested that exclusive use of fluency-enhancing strategies may result in avoidance of stuttering (Guitar, 2013; Manning & DiLollo, 2017). This seemed not to be the case in the current study. We speculate that this may be because whispering seems easy to adopt, reliable, and does not result in highly unnatural speech. The latter is not always true of other strategies, which is why many PWS are reluctant to use those (Manning & DiLollo, 2017). These aspects may also explain why the majority of participants were favorable to the idea of whispering as part of stuttering therapy and expressed interest in using a whisper-to-speech conversion app in the future.

However, no conclusive trends were observed with respect to the effect of whispered communication on overall quality of life. Note that we assumed that if participants disagreed with the statement that whispered communication had a positive effect on quality of life, this meant they did not experience a positive effect, not that they (necessarily) experienced a negative effect. It is no surprise that some people do not feel strongly about using whispered communication in the manner adopted in the current study. Namely, participants may have faced practical challenges (e.g., lack of intelligibility when using phones or during video calls). Moreover, general feelings of discomfort may arise in PWS knowing that the person they communicate with may initially not expect them to use a different voice or speech pattern during the conversation (see also Plexico et al., 2009). Future work could resolve these issues through a whisper-to-speech application which transforms whispered speech back into normal voiced speech which the person on the other side will then perceive.

A portion of our participants reported negative side-effects of whispering. Though it is generally assumed that extensive use of whispered speech may have negative effects on vocal physiology (e.g., larynx trauma, hyperfunctional voice disorder), there are currently few systematic studies that investigate this. One study by Rubin et al. (2006) demonstrated that a majority of subjects experienced increased supraglottic hyperfunction during whispering, though the authors

also indicated that whispering might not be always more harmful than normal speech (Rubin et al., 2006), a conclusion similar to that by Solomon et al. (1989). In the current study, 4 out of 17 participants reported (some) negative symptoms associated with whispering (24%), two of whom contacted the researchers in the course of the 3-week trial. This suggests that, regardless of fluency gains, using whispered speech may not be a feasible option for all people. Future clinical trials that explore long-term effects should closely monitor the type and intensity of whispering (quiet vs. high-effort) that participants apply as well as the specifics and duration of the complaints.

Clinical Implications

Based on the present results, we believe that short-term, limited use of whispered speech could be an effective addition in existing speech therapy programs. We do not recommend PWS to use whispered speech as a habitual form of communication due to practical constraints and potential negative effects on voice discussed above. Moreover, care needs to be taken to ensure that whispering does not reinforce the idea that PWS are flawed. Indeed, prior research has suggested that avoidance strategies (of which whispering may be one) lead to lower self-acceptance, and thus may be detrimental (Plexico et al., 2019). Instead, whispering may be one of many components in a personalized broad-spectrum therapeutic program where costs and benefits of each component are evaluated. Integration of small portions of whispering into otherwise normally voiced communication is also conceivable. Speech initiation (i.e., the onset of a syllable, word, or sentence) is often a major problem for PWS. Therefore, if whispering facilitates fluency, one option could be to whisper the first word or insert a whispered nonsense syllable after which one continues using voiced speech, which may relieve some of the pressure initiating vocal segments. Gradually, the whispered onset can be replaced with a soft vocal onset or even regular voice onset. Risks of voice damage should be closely monitored during any intervention using whispering, but may be markedly lower when whispering with a whisper-to-speech application on a cell phone, because in a robustly functioning app, the user will not need to force whispering to be loud enough to be intelligible. Furthermore, in these cases, there may be less concern about other people's perception and/or reaction, as the conversational partner will perceive regular (albeit transformed) voiced speech. For PWS who currently avoid speaking on the phone (e.g., because of fear of stuttering), a whisper-to-speech application could be a first step in tackling this challenge, providing PWS with a sense of control in a situation where they often feel particularly vulnerable and stressed (Georgieva, 1994; James et al., 1999; Silverman, 1997).

Limitations and Future Directions

Our participants engaged in three weeks of whispering only and as a result, it remains unclear whether more prolonged use of whispering would lead to reductions in effectiveness. Future follow-up research could extend the intervention period in order to observe effects over multiple months or even a year, which is important to further validate the long-term effectiveness of a whisper-to-speech application.

The current study did not include a control group. Therefore, participants may have been more fluent during the whispering condition out of enthusiasm for participating in the study. We cannot rule out this possibility. If this was the case, we would have expected the whispering benefit to gradually wear off during the study, as we might expect such enthusiasm to be reduced over time. Such wearing off was not observed. However, future work could collect much more convincing evidence against this possibility by recruiting a control group that engages in a condition known not to enhance fluency.

The current study aimed to test the feasibility and effectiveness of whispering. Thus, the data do not answer the question whether whispering is more or less effective than the various other fluency-inducing conditions, and whether its effects remain more or less stable over time. Future research could address these important questions by contrasting one group using whispering for a specified amount of time with groups using altered auditory feedback or other conditions for the same amount of time. This could provide valuable insight into the relative effectiveness of these various fluency-inducing conditions.

Another limitation is that the present study used a single baseline stuttering severity measure. Ideally, we would have used a second baseline measure, which would be more comparable to the post-test measurement. However, since no differences were found between pre- and post-test measures in our present dataset, a second baseline may not have been informative here. Moreover, our results regarding the effects of whispering and interest in the future application might not be fully representative of the entire population of PWS, as it is conceivable that only those who already had a positive view regarding whispered phone calls with an app signed up for our study. However, we have made several attempts to reach out to a diverse community of PWS through our advertisements, including PWS who are critical of the concept. To better understand the effectiveness of whispering on PWS' speech, future studies might include additional speech measures such as speech rate or speech naturalness. This will add insight to the overall potential of whispering as a tool for PWS.

Conclusions

Whispering can reduce the frequency and severity of stuttering during conversational speech as well as reading, and these effects remain stable over several weeks of 5-10 minutes daily use. Participants subjectively indicated that their stuttering behaviors improved and that anticipation anxiety decreased. A subset of participants reported voice complaints in conjunction with regular whispering. Therefore, extended periods of whispering, especially when intelligibility is critical (e.g., in a noisy environment, etc.) may not be recommended.

ACKNOWLEDGEMENTS

We thank Ertugrul Cavlak, Sterre Schimmel and Femke Lentjes and Stichting Support Stotteren for assistance with recruitment, interviewing participants and scoring of the SSI-4. We also thank Rianne van der Kleij for helpful suggestions on the research protocol. Finally, we thank all participants who participated in our study for their time and efforts. This study was supported and funded by

Whispp BV, a startup enterprise that aims to develop a whisper-to-speech application to assist PWS. The first author received a stipend from Whispp BV. to cover costs for this study. No further conflicts of interest declared.

AUTHOR CONTRIBUTIONS

Conceptualization RV; Investigation RV; Formal analysis RV, FV; Writing – original draft RV, FV; Writing – review & editing RV, FV; Supervision FV.

DATA AVAILABILITY

The empirical data of this study is available at https://osf.io/rbkq8

REFERENCES

Adams, M. R., & Ramig, P. (1980). Vocal characteristics of normal speakers and stutterers during choral reading. *Journal of Speech and Hearing Research, 23*(2), 457–469. https://doi.org/10.1044/jshr.2302.457

Ahmadi, F., McLoughlin, I. V., & Sharifzadeh, H. R. (2008). Analysis-by-synthesis method for whisper-speech reconstruction. In *APCCAS 2008-2008 IEEE Asia Pacific Conference on Circuits and Systems* (pp. 1280-1283). IEEE.

Andrews, G., Howie, P. M., Dozsa, M., & Guitar, B. E. (1982). Stuttering: Speech pattern characteristics under fluency-inducing conditions. *Journal of Speech, Language, and Hearing Research, 25*(2), 208–216. https://doi.org/10.1044/jshr.2502.208

Armson, J., Kiefte, M., Mason, J., & De Croos, D. (2006). The effect of SpeechEasy on stuttering frequency in laboratory conditions. *Journal of Fluency Disorders, 31*(2), 137–152. https://doi.org/10.1016/j.jfludis.2006.04.004

Barber, V. (1939). Studies in the psychology of stuttering, XV: Chorus reading as a distraction in stuttering. *Journal of Speech Disorders, 4*(4), 371–383. https://doi.org/10.1044/jshd.0404.371

Barber, V. (1940). Studies in the psychology of stuttering, XVI: Rhythm as a distraction in stuttering. *Journal of Speech Disorders, 5*(1), 29–42. https://doi.org/10.1044/jshd.0501.29

Baxter, S., Johnson, M., Blank, L., Cantrell, A., Brumfitt, S., Enderby, P., & Goyder, E. (2016). Non-pharmacological treatments for stuttering in children and adults: A systematic review and evaluation of clinical effectiveness, and exploration of barriers to successful outcomes. *Health Technology Assessment, 20*(2), 1–302. https://dx.doi.org/10.3310/hta20020

Block, S., Onslow, M., Roberts, R., & White, S. (2004). Control of stuttering with EMG feedback. *Advances in Speech Language Pathology, 6*(2), 100–106. https://doi.org/10.1080/14417040410001708521

Blomgren, M. (2013). Behavioral treatments for children and adults who stutter: A review. P*sychology Research and Behavior Management, 9*. https://doi.org/10.2147/prbm.s31450

Bloodstein, O. (1950). A rating scale study of conditions under which stuttering is reduced or absent. *Journal of Speech and Hearing Disorders, 15*(1), 29–36. https://doi.org/10.1044/jshd.1501.29

Bloodstein, O., Ratner, N. B., & Brundage, S. B. (2021). *A handbook on stuttering*. Plural Publishing.

Bosshardt, H. (2006). Cognitive processing load as a determinant of stuttering: Summary of a research programme. *Clinical Linguistics & Phonetics, 20*(5), 371–385. https://doi.org/10.1080/02699200500074321

Bruce, M. C., & Adams, M. R. (1978). Effects of two types of motor practice on stuttering adaptation. *Journal of Speech and Hearing Research, 21*(3), 421–428. https://doi.org/10.1044/jshr.2103.421

Chang, S.-E., & Guenther, F. H. (2020). Involvement of the cortico-basal ganglia-thalamocortical loop in developmental stuttering. *Frontiers in Psychology, 10*. https://doi.org/10.3389/fpsyg.2019.03088

Colcord, R. D., & Adams, M. R. (1979). Voicing duration and vocal SPL changes associated with stuttering reduction during singing. *Journal of Speech, Language, and Hearing Research, 22*(3), 468–479.

Commodore, R. W., & Cooper, E. B. (1978). Communicative stress and stuttering frequency during normal, whispered, and articulation-without-phonation speech modes. *Journal of Fluency Disorders, 3*(1), 1–12. https://doi.org/10.1016/0094-730X(78)90002-5

Craig, A. (1998). Relapse following treatment for stuttering: a critical review and correlative data. *Journal of Fluency Disorders, 23*(1), 1–30. https://doi.org/10.1016/S0094-730X(97)00027-2

Craig, A. R., & Hancock, K. (1995). Self-reported factors related to relapse following treatment for stuttering. *Australian Journal of Human Communication Disorders, 23*(1), 48–60. https://doi.org/10.3109/asl2.1995.23.issue-1.04

Cullinan, W. L., & Springer, M. T. (1980). Voice initiation and termination times in stuttering and nonstuttering children. *Journal of Speech, Language, and Hearing Research, 23*(2), 344–360. https://doi.org/10.1044/jshr.2302.344

Davidow, J. H., Bothe, A. K., Andreatta, R. D., & Ye, J. (2009). Measurement of phonated intervals during four fluency-inducing conditions. *Journal of Speech Language and Hearing Research, 52*(1), 188–205. https://doi.org/10.1044/1092-4388(2008/07-0040)

Davidow, J. H., & Scott, K. A. (2017). Intrajudge and interjudge reliability of the Stuttering Severity Instrument–Fourth Edition. *American Journal of Speech-Language Pathology, 26*(4), 1105–1119. https://doi.org/10.1044/2017_AJSLP-16-0079

Foundas, A. L., Mock, J. R., Corey, D. M., Golob, E. J., & Conture, E. G. (2013). The SpeechEasy device in stuttering and nonstuttering adults: Fluency effects while speaking and reading. *Brain and Language, 126*(2), 141–150. https://doi.org/10.1016/j.bandl.2013.04.004

Georgieva, D. (1994). Speech situations increasing stuttering in 13–16-year-old persons. *Journal of Fluency Disorders, 19*(3), 175. https://doi.org/10.1016/0094-730x(94)90101-5

Gerlach, -Houck Hope, & Constantino, C. D. (2022). Interrupting ableism in stuttering therapy and research: Practical suggestions. *Perspectives of the ASHA Special Interest Groups, 7*(2), 357–374. https://doi.org/10.1044/2021_PERSP-21-00109

Goldiamond, I. (1965). Stuttering and fluency as manipulatable operant response classes. In: L. Krasner & L. P. Ullman (Eds.), *Research in behavior modification* (pp. 106–156). Holt, Rinehart, & Winston.

Guitar, B. (2013). *Stuttering: An integrated approach to its nature and*

treatment. Lippincott Williams & Wilkins.

Hendrickson, K., & Ernest, D. (2022). The recognition of whispered speech in real-time. *Ear and Hearing, 43*(2), 554–562. https://doi.org/10.1097/AUD.0000000000001114

House, S. A., & Fisher, E. L. (2017). Hoarseness in adults. *American family physician, 96*(11), 720–728.

Ingham, R. J., Bothe, A. K., Jang, E., Yates, L., Cotton, J., & Seybold, I. (2009). Measurement of speech effort during fluency-inducing conditions in adults who do and do not stutter. *Journal of Speech Language and Hearing Research, 52*(5), 1286–1301. https://doi.org/10.1044/1092-4388(2009/08-0181)

Ingham, R. J., Bothe, A. K., Wang, Y., Purkhiser, K., & New, A. (2012). Phonation interval modification and speech performance quality during fluency-inducing conditions by adults who stutter. *Journal of Communication Disorders, 45*(3), 198–211. https://doi.org/10.1016/j.jcomdis.2012.01.004

Ingham, R. J., Moglia, R. A., Frank, P., Ingham, J. C., & Cordes, A. K. (1997). Experimental investigation of the effects of frequency-altered auditory feedback on the speech of adults who stutter. *Journal of Speech Language and Hearing Research, 40*(2), 361–372. https://doi.org/10.1044/jslhr.4002.361

James, S. E., Brumfitt, S. M., & Cudd, P. A. (1999). Communicating by telephone. Views of a group of people with stuttering impairment. *Journal of Fluency Disorders, 24*(4), 299–317. https://doi.org/10.1016/S0094-730X(99)00019-4

Janke, M., Wand, M., Heistermann, T., Schultz, T., & Prahallad, K. (2014). Fundamental frequency generation for whisper-to-audible speech conversion. In: *2014 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)* (pp. 2579–2583). IEEE.

Jeffreys, H. (1961) *Theory ofprobability. 3rd Edition*. Clarendon Press.

Johnson, W., & Rosen, L. (1937). Studies in the psychology of stuttering: VII: Effect of certain changes in speech pattern upon frequency of stuttering. *Journal of Speech Disorders, 2*(2), 105–110. https://doi.org/10.1044/jshd.0202.105

Kalinowski, J., Stuart, A., Sark, S., & Armson, J. (1996). Stuttering amelioration at various auditory feedback delays and speech rates. *International Journal of Language & Communication Disorders, 31*(3), 259–269. https://doi.org/10.3109/13682829609033157

Kalinowski, J., Stuart, A., Rastatter, M. P., Snyder, G., & Dayalu, V. (2000). Inducement of fluent speech in persons who stutter via visual choral speech. *Neuroscience Letters, 281*(2–3), 198–200. https://doi.org/10.1016/S0304-3940(00)00850-8

Kell, C. A., Neumann, K., Behrens, M., von Gudenberg, A. W., & Giraud, A.-L. (2018). Speaking-related changes in cortical functional connectivity associated with assisted and spontaneous recovery from developmental stuttering. *Journal of Fluency Disorders, 55*, 135–144. https://doi.org/10.1016/j.jfludis.2017.02.001

Kikuchi, Y., Umezaki, T., Adachi, K., Sawatsubashi, M., Yamaguchi, Y., Murakami, D., & Nakagawa, T. (2018). Evaluation of vocal fold motion during blocks in adults who stutter. *International Archives of Communication Disorder, 1*(006). https://doi.org/10.23937/iacod-2017/1710006

Konno, H., Kudo, M., Imai, H., & Sugimoto, M. (2016). Whisper to normal speech conversion using pitch estimated from spectrum. *Speech Communication, 83*, 10–20. https://doi.org/10.1016/j.specom.2016.07.001

Kourtis, D., Sebanz, N., & Knoblich, G. (2010). Favouritism in the motor system: social interaction modulates action simulation. *Biology Letters, 6*(6), 758–761. https://doi.org/10.1098/rsbl.2010.0478

Lincoln, M., Packman, A., & Onslow, M. (2006). Altered auditory feedback and the treatment of stuttering: A review. *Journal of Fluency Disorders, 31*(2), 71–89. https://doi.org/10.1016/j.jfludis.2006.04.001

Manning, W. H., & DiLollo, A. (2017). *Clinical decision making in fluency disorders*. Plural Publishing.

Lunney, G. H. (1970). Using analysis of variance with a dichotomous dependent variable: An empirical study 1. *Journal of Educational Measurement, 7*(4), 263–269. https://doi.org/10.1111/j.1745-3984.1970.tb00727.x

Martin, R., & Haroldson, S. K. (1979). Effects of five experimental treatments on stuttering. *Journal of Speech, Language, and Hearing Research, 22*(1), 132–146. https://doi.org/10.1044/jshr.2201.132

Monoson, P., & Zemlin, W. R. (1984). Quantitative study of whisper. F*olia Phoniatrica et Logopaedica, 36*(2), 53–65. https://doi.org/10.1159/000265721

O'Donnell, J. J., Armson, J., & Kiefte, M. (2008). The effectiveness of SpeechEasy during situations of daily living. *Journal of Fluency Disorders, 33*(2), 99–119. https://doi.org/10.1016/j.jfludis.2008.02.001

Perkins, W., Rudas, J., Johnson, L., & Bell, J. (1976). Stuttering: Discoordination of phonation with articulation and respiration. *Journal of Speech Language and Hearing Research, 19*(3), 509–522. https://doi.org/10.1044/jshr.1903.509

Perrotin, O., & McLoughlin, I. V. (2020). Glottal flow synthesis for whisper-to-speech conversion. *IEEE/ACM Transactions on Audio, Speech, and Language Processing, 28*, 889–900. https://doi.org/10.1109/TASLP.2020.2971417

Plexico, L. W., Manning, W. H., & Levitt, H. (2009). Coping responses by adults who stutter: Part I. Protecting the self and others. *Journal of Fluency Disorders, 34*(2), 87–107. https://doi.org/10.1016/j.jfludis.2009.06.001

Plexico, L. W., Erath, S., Shores, H., & Burrus, E. (2019). Self-acceptance, resilience, coping and satisfaction of life in people who stutter. *Journal of Fluency Disorders, 59*, 52–63. https://doi.org/10.1016/j.jfludis.2018.10.004

Pollard, R., Ellis, J. B., Finan, D., & Ramig, P. R. (2009). Effects of the SpeechEasy on objective and perceived aspects of stuttering: a 6-month, phase I clinical trial in naturalistic environments. *Journal of Speech Language and Hearing Research, 52*(2), 516–533. https://doi.org/10.1044/1092-4388(2008/07-0204)

Rami, M. K., Kalinowski, J., Rastatter, M. P., Holbert, D., & Allen, M. (2005). Choral reading with filtered speech: Effect on stuttering. *Perceptual and Motor Skills, 100*(2), 421–431.

Riley, G. (2009). *SSI-4 stuttering severity instrument fourth edition.* Pro-Ed.

Rosen, C. A., Anderson, D., & Murry, T. (1998). Evaluating hoarseness: keeping your patient's voice healthy. *American Family Physician, 57*(11), 2775–2782.

Rouder, J. N., Speckman, P. L., Sun, D., Morey, R. D., & Iverson, G. (2009). Bayesian t tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review, 16*(2), 225–237. https://doi.org/10.3758/PBR.16.2.225

Rubin, A. D., Praneetvatakul, V., Gherson, S., Moyer, C. A., & Sataloff, R. T. (2006). Laryngeal hyperfunction during whispering: reality or myth? *Journal of Voice, 20*(1), 121–127 https://doi.org/10.1016/j.jvoice.2004.10.007

Saltuklaroglu, T., Kalinowski, J., & Stuart, A. (2010). Refutation of a therapeutic alternative? A reply to Pollard, Ellis, Finan, and Ramig (2009). *Journal of Speech Language and Hearing Research, 53*(4), 908–911. https://doi.org/10.1044/1092-4388(2009/09-0128)

Schilbach, L., Timmermans, B., Reddy, V., Costall, A., Bente, G., Schlicht, T., & Vogeley, K. (2013). Toward a second-person neuroscience. *Behavioral and Brain Sciences, 36*(4), 393–414. https://doi.org/10.1017/S0140525X12000660

Silverman, F. H. (1997). Telecommunication relay services: An option for stutterers. *Journal of Fluency Disorders, 22*(1), 63–64. https://doi.org/10.1016/s0094-730x(96)00087-3

Smith, A., & Weber, C. (2017). How stuttering develops: the multifactorial dynamic pathways theory. *Journal of Speech Language and Hearing Research, 60*(9), 2483–2505. https://doi.org/10.1044/2017_jslhr-s-16-0343

Solomon, N. P., McCall, G. N., Trosset, M. W., & Gray, W. C. (1989). Laryngeal configuration and constriction during two types of whispering. *Journal of Speech Language and Hearing Research, 32*(1), 161–. https://doi.org/10.1044/jshr.3201.161

Stuart, A., Kalinowski, J., & Rastatter, M. P. (1997). Effect of monaural and binaural altered auditory feedback on stuttering frequency. *The Journal of the Acoustical Society of America, 101*(6), 3806–3809. https://doi.org/10.1121/1.418387

Stuart, A., Kalinowski, J., Rastatter, M. P., & Lynch, K. (2002). Effect of delayed auditory feedback on normal speakers at two speech rates. *The Journal of the Acoustical Society of America, 111*(5), 2237. https://doi.org/10.1121/1.1466868

Stuart, A., Kalinowski, J., Rastatter, M. P., Saltuklaroglu, T., & Dayalu, V. (2004). Investigations of the impact of altered auditory feedback in-the ear devices on the speech of people who stutter: Initial fitting and 4-month follow up. *International Journal of Language & Communication Disorders, 39*(1), 93–113.

Stuart, A., Kalinowski, J., Saltuklaroglu, T., & Guntupalli, V. K. (2006). Investigations of the impact of altered auditory feedback in-the-ear devices on the speech of people who stutter: One-year follow-up. *Disability and Rehabilitation, 28*(12), 757–765. https://doi.org/10.1080/09638280500386635

Tichenor, S. E., & Yaruss, J. S. (2020). Recovery and relapse: Perspectives from adults who stutter. *Journal of Speech, Language, and Hearing Research, 63*(7), 2162–2176. https://doi.org/10.1044/2020_JSLHR-20-00010

Trotter, W. D., & Silverman, F. H. (1974). Does the effect of pacing speech with a miniature metronome on stuttering wear off? *Perceptual and Motor Skills, 39*(1, Pt 2), 429–430. https://doi.org/10.2466/pms.1974.39.1.429

Tsunoda, K., Niimi, S., & Hirose, H. (1994). The roles of the posterior cricoarytenoid and thyropharyngeus muscles in whispered speech. *Folia Phoniatrica et Logopaedica, 46*(3), 139–151. https://doi.org/10.1159/000266306

Unger, J. P., Glück, C. W., & Cholewa, J. (2012). Immediate effects of AAF devices on the characteristics of stuttering: A clinical analysis. *Journal of Fluency Disorders, 37*(2), 122–134. https://doi.org/10.1016/j.jfludis.2012.02.001

Watermeyer, B., & Kathard, H. (2016). To be or not to be: Stuttering and the human costs of being "un-disabled." *International Journal of Speech-Language Pathology, 18*(1), 11–19. https://doi.org/10.3109/17549507.2015.1060528

Woolf, G. (1967). The assessment of stuttering as struggle, avoidance, and expectancy. *International Journal of Language & Communication Disorders, 2*(2), 158–171. https://doi.org/10.3109/13682826709031315

RECEIVED 17.09.2022 | ACCEPTED 07.02.2023

SUPPLEMENTARY MATERIAL

Final Evaluation Questionnaire

Please indicate how much you agree with the following statements (1 = *strongly disagee*, 2 = *disagree*, 3 = *neutral*, 4 = *agree*, 5 = *strongly agree*)

1. Whispering (during communication) improved my fluency compared to speaking normally.
2. Whispering (during communication) reduced my stuttering anxiety about stuttering compared to speaking normally.
3. When I whispered I did not anticipate stuttering as much as compared to when I spoke normally.
4. During whispered speech I did not experience any speech blocks / my speech blocks were less severe compared to normal speech.
5. When I whispered I could more easily manage my stuttering compared to when I spoke normally.
6. When I whispered I could still communicate effectively with my conversational partner.
7. I felt confident using whispering when communicating with another person.
8. My overall confidence in speech and communication has been improved since I regularly whisper.
9. My overall wellbeing has increased since I regularly whisper.
10. I did not experience adverse side effects as a result of whispering occasionally.
11. I would recommend whispering as a fluency tool to other people who stutter.
12. If an app would exist with which I could whisper on the phone, while the person on the other side of the line perceives my own normal and natural voice without delay (thus not realizing that I am actually whispering), I would be interested and considering using it.
13. I think that such an app could make a useful contribution to stuttering-therapy.

SSI Scores: Time × Condition

The main manuscript focused on percentage of stuttered syllables (%SS) as an outcome measure. To further explore wear-off effects we also analyzed SSI which is a combination of percentage of stuttered syllables that collapses across tasks (conversation and reading) and hence may be more sensitive.

We found that whispering was associated with a lower overall SSI-score compared to normal speech, $F(1, 15) = 23.31$, $p < .001$, $\eta^2 = 0.61$. This was true and to a similar extent during both pre (reduction 37.5%, $p = .001$) and post (38.8%, $p < .001$). To rule out that this result may be due to a violation of statistical assumptions in the tests used, we calculated the nonparametric Wilcoxon signed-rank which indicated the same pattern (pre-test: $Z = -3.24$, $p = .001$; post-test: $Z = -3.30$, $p = .001$). The main effect of time was not statistically significant, $F(1, 15) = 1.81$, $p = .20$, $\eta^2 = 0.11$], nor was the time × condition interaction, $F(1, 15) = 1.55$, $p = .23$, $\eta^2 = 0.09$].