

Review of Telehealth Stuttering Management

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Abstract

Objective: Telehealth is the use of communication technology to provide health care services by means other than typical in-clinic attendance models. Telehealth is increasingly used for the management of speech, language and communication disorders. The aim of this article is to review telehealth applications to stuttering management. **Methods:** We conducted a search of peer-reviewed literature for the past 20 years using the Institute for Scientific Information Web of Science database, PubMed: The Bibliographic Database and a search for articles by hand. **Results:** Outcomes for telehealth stuttering treatment were generally positive, but there may be a compromise of treatment efficiency with telehealth treatment of young children. Our search found no studies dealing with stuttering assessment procedures using telehealth models. No economic analyses of this delivery model have been reported. **Conclusion:** This review highlights the need for continued research about telehealth for stuttering management. Evidence from research is needed to inform the efficacy of assessment procedures using telehealth methods as well as guide the development of improved treatment procedures. Clinical and technical guidelines are urgently needed to ensure that the evolving and continued use of telehealth to manage stuttering does not compromise the standards of care afforded with standard in-clinic models.

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Introduction

Telehealth can be described as the use of available technology to provide health care services by means other than typical in-clinic attendance models. This health care innovation was recognized as a potentially valuable contribution to global health by the World Health Organization [1, p.10], and defined by that organization as:

The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities.

The procedure is known variously as, telemedicine, health telematics, telecare, telepractice telerehabilitation, teleaudiology, telespeech and speech teletherapy. However, the prefix 'tele', implying telecommunications, is outdated for current client service provision technology. The term eHealth encompasses the broader use of technology for health care. For example, self-managed interventions such as computer-based treatment programs can be included under eHealth health care services. The term eHealth also includes the transmission and storage of data and information for the purposes of diagnosis,

patient monitoring and record keeping using dedicated software applications, text messaging, e-mail and fax [2].

The American Speech and Hearing Association (ASHA) adopted the term telepractice to avoid the 'misperception that these services are used only in health care settings' [3]. ASHA further endorses this as an appropriate service delivery model for the professions of audiology and speech-language pathology [4]. At the time of preparing this review, Speech Pathology Australia is in the process of developing a position statement on the topic and as such a term has not yet been endorsed. The term telehealth will be used in this article to refer to the broader use of technology for stuttering management. The term includes direct and real-time speech-language pathologist interaction with clients who stutter as well as Internet-based computer programs that might elsewhere be categorized as eHealth.

The practice of telehealth is widely used in the management of a range of speech, language and communication disorders as well as dysphagia [4]. Telehealth extends the provision of services by specialist speech-language pathologists without increasing travel time or costs associated with servicing large or remote areas. Direct speech-language pathologist administered telehealth services typically make use of the telephone, dedicated site-based videoconferencing facilities, and personal computer-based videoconferencing programs. Venues for the administration of services using videoconferencing facilities can include dedicated videoconferencing sites, schools, universities, early childcare centers, community health centers, medical centers, outpatient clinics, rehabilitation centers and hospitals, residential facilities, corporate settings, the client's home and workplace [3].

With home-based telephone or personal computer-based videoconferencing for direct and real-time delivery of intervention, the setup cost is minimal with much modern webcam software being free to clients and service providers. Further, complex clinical infrastructure is not needed. From client and caregiver viewpoints, treatment efficiency and convenience improve by reducing the need to travel to a clinic or dedicated site for consultations or regular appointments. Increasingly, the provision of telehealth services has been recognized to benefit not only those who live in rural or remote areas, isolated from standard or specialized clinical services, but also urban dwellers who experience difficulty accessing clinics or specialist services due to disability, work commitments, family constraints and transportation difficulties [5, 6]. For example, for families with young children, this can eliminate the practical constraints of having to take a

child to the clinic and back, possibly with one or more siblings [6]. Treatment outcomes may also be enhanced when treatment targets are taught and practiced in the client's everyday environment [7]. Additionally, it has been argued that home-based treatment can be facilitated by the continued presence of cultural and community support networks [8, 9].

Previous Reviews of Telehealth Delivery of Speech-Language Pathology Services

Hill and Theodoros [10] conducted a comprehensive review of the literature on the use of telehealth and identified 13 empirical studies exclusively about or including telehealth applications in speech-language pathology in general. Two of these studies pertained to stuttering and others reported on the application of telehealth services to childhood speech and language disorders, acquired neurological communication disorders, and voice disorders. The authors concluded that the literature provided encouraging results. Of the studies reviewed, most reported on the efficacy of telehealth. Up to the time of their review [10], the authors observed the bulk of telehealth applications to speech-language pathology had involved the testing of new methods with 'proof of concept' rather than substantial empirical studies.

In their concluding remarks, Hill and Theodoros [10] noted that research to date had been scant on details needed for replication, and had used small sample sizes. They also indicated that no economic analysis of the procedures had been conducted, and that traditional speech-language pathology outcome measures were absent. The authors argued that evaluation of the technology used is critical with this type of treatment development, but none had occurred at the time of writing. Finally, they noted that telehealth interventions had been applied only to a limited range of speech and language disorders.

Hill and Theodoros [10] suggested the need for future research to focus on the assessment of client outcomes including client and speech-language pathologist satisfaction, evaluation of processes and procedures, and, importantly, a cost-benefit analysis. The development of protocols and guidelines in different environments for specific client groups was needed, with consideration of the type of technology available to service providers and the wider community including clients. Importantly, they called for a scientific approach for future research.

Six years after the Hill and Theodoros review [10], Mashima and Doarn [11] reported that the number of

speech-language pathology telehealth publications had grown to 40, 28 of which were in peer-reviewed journals. Mashima and Doarn [11] overviewed research that had been conducted with specific disorders including neurological communication disorders, fluency disorders, voice disorders, dysphagia, and childhood speech and language disorders. The authors focused their discussion on several topics that were gleaned from those studies reviewed. Those topics included the technology used in telehealth delivery, client and speech-language pathologist satisfaction, advantages of telehealth, challenges and barriers to the application of telehealth and future directions.

Like Hill and Theodoros [10], Mashima and Doarn [11, p. 1102] also noted that 'the existing literature consists primarily of pilot studies and anecdotal accounts of telehealth applications rather than large, well-controlled, randomized clinical trials'. In order for telehealth applications to be integrated into routine clinical and administrative practice, they highlighted the need for evidence from clinical trials including clinical efficacy and economic analyses. They concluded that further research was needed to develop guidelines and standards for clinical practice, as well as technical requirements, to ensure that telehealth applications do not compromise the standards of care afforded with traditional in-clinic models.

To the present authors' knowledge, there has been no detailed review of the application of telehealth specifically to the management of stuttering. This article provides such a review. The discussion focuses on clinical research to date for stuttering management and identifies potential barriers to the uptake of telehealth for this client group. Directions for future research are outlined.

Methodology for the Present Review

We conducted a review of peer-reviewed speech-language pathology literature using the Institute for Scientific Information Web of Science database and PubMed: the Bibliographic Database. Search terms included 'stuttering' and 'telepractice' or 'telerehabilitation' or 'telehealth' or 'telematics' or 'telemedicine'. A search for articles by hand was also conducted from reference lists and bibliographies of journal articles, edited books and book chapters. Conference papers, posters and unpublished dissertations were not reviewed.

For this review, we define the taxonomy used for clinical-outcome research and applied to speech-language pathology [12–14]. This taxonomy includes five phases of research evidence.

- Phase I preliminary research involves testing the safety and feasibility of a treatment. Studies are usually conducted with few participants and include case studies, retrospective studies and small group pre-post studies.

- Phase II research involves the continued testing of the safety and viability of a treatment, in addition to investigating treatment responsiveness, effect and dosage. Small group studies are investigated in Phase II research, for example, experimental versus control studies as well as case studies and single-subject studies. During this phase of research, measurement instruments are selected or developed, primary outcomes are determined and protocols and administrative manuals developed.
- Phase III research involves testing the efficacy of a treatment when administered under optimal conditions. Phase III research designs include parallel group experiments, for example, comparing an experimental treatment group with a control condition, a different treatment or treatments. Participants are randomly allocated to one of the groups. Participant numbers are determined by power calculations. Phase III trials provide strong evidence of effect sizes.
- Phase IV research involves continued investigation of the efficacy of a treatment with different populations, for example, subpopulations. Phase IV research investigates outcomes when variations to the treatment protocol are applied, for example, different forms of service delivery and varying levels of clinical training. At this level, the effectiveness of a treatment in typical day-to-day clinical settings is investigated. Designs can include contrasting results with a control group or parallel-group experiments.
- Phase V research aims to determine treatment responders with typical service delivery models. In addition, cost-effectiveness, cost-benefit, quality of life and client satisfaction are investigated. Phase V research involves large group studies and multiple replication single-subject studies. As results accumulate, meta-analysis is used at both phase IV and phase V levels to synthesize effectiveness outcomes of phase III studies.

Results

Eleven articles were found that consisted of anecdotal report, phase I and phase II research. Four categories of telehealth applications to stuttering management were identified. These were: (1) real-time delivery of treatment using the telephone; (2) dedicated site-based videoconferencing facilities; (3) home-based videoconferencing using personal computers and webcams, and (4) Internet-driven computer programs. These articles are tabulated in the Appendix.

Telehealth Treatment for Children Who Stutter

Telephone Treatment Delivery

Three studies have reported telephone delivery of treatment with young children who stutter. In the earliest study, Harrison et al. [15] presented a case study of a British boy with a long history of stuttering, who was treated from Australia with the Lidcombe Program. He was aged

5 years and 10 months at the time of initial contact. Methods were regular telephone consultations, supplemented by mail delivery of video and audiotapes to guide and evaluate the treatment process. Telephone consultations averaged once every 11.5 days, with a median number of 12.5 days between calls, and a median call duration of 45 min.

Pretreatment stuttering severity ranged from 12.4 to 17.7% syllables stuttered (%SS) and, subsequent to telehealth intervention, was nearly zero at 23 months' follow-up. The authors argued that, because of the participant's age, such a result was not likely to have occurred due to natural recovery. The treatment required 25 telephone consultations for completion of stage 1. This is much more than the established Lidcombe Program benchmark for standard presentation, based on four file audits, one clinical trial, and one prospective follow-up, $n = 692$, range 11–17, median 13.9 sessions to stage 2 [16].

Following the Harrison et al. [15] study, Wilson et al. [17] reported on a phase I study of a home-based telephone treatment with the Lidcombe Program. Wilson et al. [17] acknowledged the in-principle superiority of audiovisual methods, but argued that a low-tech approach was needed if the purpose of telehealth is to improve treatment accessibility. They reasoned that dedicated audiovisual telehealth infrastructure was not available at the time to make such an approach viable. Additionally, in Australia, at the time the study was conducted, bandwidth adequate for telehealth was not universally available to the target population of rural dwellers [18]. That combined with limited availability of personal computer Internet access made videoconferencing not a viable option for most families.

In the Wilson et al. [17] study participants were 5 children younger than 6 years who received an adaptation of the Lidcombe Program suitable for delivery by telephone. A potential improvement on the Harrison et al. [15] study, the treatment was supplemented by audiovisual training materials, which were provided to parents. As was the case with the former study [15], parents sent to the speech-language pathologist by mail recordings of their children stuttering and of them doing the Lidcombe Program procedures. Eight families were recruited but three (38%) withdrew during treatment. Follow-up data were unavailable for one of the 5 children who completed the treatment. This high dropout rate needs to be taken into account when interpreting what this study suggests about the acceptability of this model of telehealth intervention to rural families.

Stuttering pre-treatment for the 5 children ranged from 2 to 20%SS. Final data for the 4 children remaining in the program at 12 months post-treatment were 0.2, 0.6,

1.3, and 1.4%SS, suggesting an efficacious treatment. As with all nonrandomized early stuttering interventions, however, there is no way of assessing the extent to which natural recovery contributed to those results. The 4 children for whom long-term data were available required a mean of 27 (range: 20–34) consultations to complete stage 1, with a mean session duration of 31 (range: 22–41) min. These data confirmed the finding of Harrison et al. [15] that the delivery of the Lidcombe program using the telephone may take longer than in-clinic treatment [16].

In a further study, using the low-tech telephone method, Lewis et al. [19] conducted a phase II randomized control study with a telehealth treatment group compared to a no-treatment control group. The authors again justified the delivery method with reference to the unavailability of more sophisticated technology at the time. The study did, however, foreshadow the future viability of videoconferencing for early stuttering intervention with technological developments. The dropout rate (18%) was less of a problem than that reported in the earlier study by Wilson et al. [17]. The study initially began with 9 children randomized to the telehealth group and 13 to the control group, however, only 8 and 10 children, respectively, were available for follow-up 9 months later. Using a definition of 80% stuttering reduction as a 'responder', 6 of the 8 telehealth children responded but only 2 of the 10 control children responded. Mean scores at randomization for the experimental and control groups were 6.7%SS and 4.5%SS, respectively. At 9 months post randomization, mean scores were 1.1%SS (experimental group) and 1.9%SS (control group). There was a 69% decrease in stuttering frequency in the experimental group compared with the control group at 9 months post randomization. The mean number of telephone consultations for the telehealth group was 49 (range: 27–98), with a mean consultation duration of 33 (range: 26–52) min, further verifying that the low-tech telehealth format required longer than the standard in-clinic Lidcombe Program delivery [16]. Survey data confirmed the recurring impression that parents found telehealth treatment to be a positive experience.

Audiovisual Treatment Delivery

Three articles report on telehealth stuttering treatment with young children using videoconferencing. In the first report Kully [20] indicated that the Institute for Stuttering Treatment and Research in Edmonton had been using audiovisual telehealth methods routinely, and had extended them to the application of the Lidcombe Program for preschool aged children who stutter. However, details about adaptations made to the treatment for this mode of

delivery were not reported. At that time, 'more than 80 telehealth sessions with clients ranging in age from 3 to 38' [20, p. 7] had been conducted by the Institute, using dedicated videoconferencing facilities in rural areas. With the exception of one 10-year-old, who received his treatment entirely with telehealth, all cases were managed with a combination of in-clinic and telehealth service.

All clients and families were satisfied with the method, finding it preferable to the time and financial cost of traveling to Edmonton for treatment. There were reported to be some challenges associated with not having children physically in the clinic room. For example, books and pictures could easily be presented and discussed using the video link, however speech-language pathologist resources such as games or activities could not. The families therefore used materials from the home during the treatment sessions. Second, the speech-language pathologist could not directly demonstrate treatment procedures with the child. Instead the speech-language pathologist needed to provide clear instructions and feedback to the parents with an emphasis on the development of problem-solving skills. The author reported that children and adults adapted quickly to the audiovisual system. In cases where operating bandwidth was poor, speech-language pathologists worked only with the audio signal, and had a telephone backup available for cases when the connection was lost. This report foreshadowed technological developments that would obviate the need for dedicated telehealth infrastructure, and allow treatment to occur in client homes.

A phase I study of 6 clients, ages 4, 5, 7, 12, 17 and 19 years, further demonstrated the viability of using dedicated videoconferencing facilities for stuttering management [21]. The service operated between a Montreal clinic and a primary care center in a remote area of Quebec. Two participants were treated with 12 one-hour sessions, and 4 received 20 one-hour treatment sessions. Participants presented to every videoconferencing session with no failures to attend. The article did not provide treatment details, even though it is certain that different methods would have been required for the range of ages represented: preschool, school-age, adolescent, and young adult. The only information available is that 'the type of therapy given consisted of currently accepted and well used procedures documented by various authors' [21, p. 254]. Another problem with determining outcomes for the study is that pre-treatment, post-treatment and 6-month follow-up assessments were based on a %SS measure collected from in-clinic video recordings, rather than speech recordings during everyday conversations, as is the generally accepted method for modern clinical re-

search. Additionally, while all participants demonstrated a reduction in stuttering frequency post-treatment, stuttering reductions were modest, with mean reductions of 48% post-treatment and 46% at follow-up,¹ which are well below benchmarks established with clinical research of those age groups [22–27]. Pre-treatment %SS ranged from 13 to 36%SS, post-treatment from 2 to 26%SS, and at the end of follow-up from 4 to 32%SS. Two of the youngest participants continued to demonstrate a decrease in stuttering frequency during the maintenance period. The remaining 4 participants demonstrated varying increases in stuttering frequency at follow-up.

The treating speech-language pathologist gave favorable ratings to the 'quality of the therapeutic relationship with the patient', 'degree of control over the patient during treatment', and 'compliance with the instructions given by the speech-language pathologist' [21, p. 255, table 1]. All clients and parents were satisfied with the image and sound quality, the 'therapeutic contact' and none were 'concerned about treatment from a distance' [21, p. 256, table 2].

A phase I study evaluated the Lidcombe Program delivered using the Internet and videoconferencing software [28]. Broadband Internet access was used with personal computers and webcams in the participant's homes. Two boys and 1 girl and their parents participated. The children were aged 3 years and 6 months, 4 years and 3 months, and 4 years and 9 months at the start of treatment. Lidcombe Program procedures were adhered to with some modifications. The treating speech-language pathologist's impression was that more time was spent describing procedures to parents rather than modeling such with the child. All treatment sessions were conducted using the Internet with the exception of one occasion. In this case a telephone connection was used to improve audio quality.

Speech samples were obtained from telephone calls and consisted of two 10-min audio recordings of the child talking with a family member at home and with a non-family member away from the home. The mean of the two beyond-clinic recordings of each child was 3.7, 4.1 and 2.6%SS pre-treatment. At the 6-month point following entry into stage 2 (maintenance), all 3 children had a stuttering severity of less than 1.0%SS. Participant 1 had an 81% reduction in stuttering severity, participant 2 had a 99% reduction and participant 3 had a 69% reduction.

Participants required a mean of 34 (range: 26–39) treatment sessions to complete stage 1. The mean number

¹ The report states 'a mean 52% decrease in the frequency of stuttering' [21, p. 257]; however, we believe this to be an error based on the contents of table 4 [21].

of weeks to complete stage 1 was 40 (range 29–49), which included those weeks that treatment was not conducted to due to illness, holidays, and other parental commitments. Parent-reported stuttering severity ratings were consistent with %SS measures. Parents were positive about receiving this telehealth treatment approach.

The results of this preliminary study suggest that home-based webcam delivery of the Lidcombe Program may be efficacious. However, the mean of 34 treatment sessions is still considerably higher than current benchmarks for standard in-clinic procedures.

Telehealth Treatment for Adolescents and Adults Who Stutter

Telephone Treatment Delivery

A phase I study of the Camperdown Program using the telephone was conducted by O'Brian et al. [29]. The authors did not justify their delivery choice at a time of emerging Internet webcam technology. Replicability of the study was facilitated with details of departures from the in-clinic treatment version. Participants were 10 adults seeking stuttering treatment but who could not attend the clinic regularly. In 4 cases this was because of geographic isolation, and in 6 cases because of work commitments. All participants completed the treatment.

Primary outcome measures were obtained from three audio recordings using the telephone, one talking to a speech-language pathologist and two talking to strangers. All recordings were clinic-initiated and unscheduled. The mean %SS scores for the calls made by the strangers were 7.2 pre-treatment, 1.4 immediately post-treatment and 1.9 at 6 months post-treatment. At 6 months post-treatment, the mean stuttering reduction for participants was 74%. Pretreatment stuttering severity and a prior treatment history did not affect outcomes.

Self-reported stuttering severity scores for five everyday speaking situations mostly confirmed the %SS results. Speech naturalness scores were also favorable. In contrast to the telehealth applications of treatment with preschool stuttering children discussed above, this study suggested improved efficiency with adult telehealth speech restructuring. A mean of 8 (range: 5.2–16.9) clinical hours were required to reach the maintenance stage of the program. Participants who received standard Camperdown Program in the O'Brian et al. [30] study required a group mean of 20 h (range 13–29) to reach maintenance.

The first study to compare standard in-clinic delivery of treatment with telehealth was a phase II randomized con-

trol study of the Camperdown Program [31]. This study aimed to establish that telephone delivery of the Camperdown Program was not inferior to traditional in-clinic delivery in terms of speech treatment outcomes. This study used the same low-tech method as the former phase I study in which the Camperdown Program was administered using the telephone [29]. Participants were 40 adults (20 standard in-clinic, 20 telehealth) who were seeking speech treatment. The primary outcome measure, %SS, was obtained from the clinic-initiated and unscheduled telephone calls used in the former study [29], including one from a speech-language pathologist and two from strangers, pre-treatment and 9 months post randomization. Three participants (2 participants from the standard group and 1 from the telehealth group) withdrew during the study.

Pretreatment group mean score for the standard treatment arm was 5.4%SS and 6.9%SS for the telehealth arm. The authors used intention-to-treat analysis. This involved including and analyzing the last data obtained from participants in the case of those who withdrew from the study and for whom final data was unavailable [32]. With the last observation carried forward, 9 months' post-randomization group mean for the standard treatment arm was 2.7%SS and the telehealth arm was 3.0%SS. However, adjusting for baseline stuttering rate, the telehealth arm had 0.8%SS lower stuttering rate than the standard treatment arm. The authors reported a mean of 10 h 17 min speech-language pathologist contact hours for the telehealth group and 12 h 54 min for the standard group. This result was statistically and clinically significant, with the telehealth group requiring an adjusted 3 h 41 min less treatment time than the standard group.

With a 9-point self-administered stuttering severity scale where 1 = 'no stuttering', 2 = 'extremely mild stuttering' and 9 = 'extremely severe stuttering', the mean daily score for telehealth participants pre-treatment was 3.9 and for the standard treatment group 3.8. Nine months post randomization, the telehealth group mean daily score was 2.3 and the standard treatment group mean daily score was 2.4.

Audiovisual Treatment Delivery

Kully [33], in an anecdotal report, described the successful follow-up of an adult client using dedicated videoconferencing facilities. The follow-up program commenced after the client received an intensive, residential treatment at the Institute for Stuttering Treatment Research. The client received regular telehealth contacts that became less frequent and reported satisfaction with the method. This was the first study to demonstrate that

audiovisual telehealth methods were adequate for judging the presence or absence of stuttering moments. However, no data were presented to substantiate that claim.

The first evidence for using personal computers for home-based videoconferencing of stuttering treatment for adolescents was described in a phase I study [34]. Participants were 3 adolescents: 2 boys aged 13 and 15 years and a girl aged 16 years. The Camperdown Program used in this study was conceptually the same as the in-clinic version with some adaptations for audiovisual telehealth delivery. The treatment was conducted using a laptop, webcam and dedicated public domain videoconferencing software. Additionally, an Internet-based audio recording program was used to provide the speech-language pathologist with examples of the participants conducting speech drills, along with an audiovisual recording program that allowed the speech-language pathologist to record and play back the participants' speech to them during treatment sessions. The home-based videoconference facility provided the opportunity for parents to participate in the treatment session, which occurred in the case of 1 participant. The rationale for the introduction of video teleconferencing to stuttering treatment was justified by the suitability of that medium for adolescents. Modern adolescents use computers for social networking [35] and hence could be expected to adapt their use to stuttering treatment. Additionally, adolescents typically value independence [36], and home-base stuttering interventions can provide that independence in a private environment without reliance on others for transport to and from a clinic.

The primary outcome was collected with similar methods to the telehealth stuttering treatment studies for adults [29, 31]. Percent syllables stuttered was measured from two 10-min conversations of participants conversing with a stranger during unscheduled, clinic-initiated telephone calls pre-treatment and 1 day, 6 months and 12 months after entry to the Camperdown Program maintenance program. One participant reduced stuttering by around half: 16.7%SS pre-treatment to 8.4%SS post-treatment. The other 2 participants attained better outcomes, with equivalent reductions from 21.8 to 2.5%SS and 9.2 to 1.6%SS. The participants required treatment times of 8 h 18 min, 15 h 0 min, and 9 h 35 min, a result which was consistent with the results from the phase I study comparing telephone delivery of the Camperdown Program with traditional in-clinic treatment with adults [31]. Self-report stuttering severity scores for speaking situations confirmed those results.

A potentially important feature of this data set for consideration if it were to be replicated with subsequent ado-

lescent telehealth studies is that stuttering reductions appeared not to be associated with situation avoidance during everyday life. Avoidance was measured by participants using a 3-point scale where 1 = never avoided, 2 = sometimes avoided and 3 = usually avoided. It may be the case that the social anxiety typically associated with adult stuttering [for a review, see 37] may not resolve during adolescence with speech rehabilitation, and dedicated anxiety management techniques may be required. The adolescent participants 'viewed the treatment as helpful and comfortable', the only problem for them being 'occasional technical difficulty' [37, p. 376].

Internet-Driven Computer Programs

The potential use of technology to deliver stuttering treatment was described in a phase I study of an Internet-driven purpose-built computer program designed to treat adults who stutter without clinician input. In this feasibility study, 2 participants completed a computerized adaptation of the Camperdown Program delivered using the Internet [38]. The program retained most of the concepts of the Camperdown Program; however, the participants did not complete its final maintenance phase. The authors acknowledged the critical importance of a structured maintenance stage for the treatment of stuttering but argued the aim of the study was to test the 'feasibility of the program to reduce stuttering' [38, p. 120] without clinician input. The program consisted of nine phases. Participants completed each phase in consecutive order as presented by the program. Phases were only 'unlocked' when participants had satisfactorily completed the previous phase according to inbuilt criteria. Technical support independent of the researchers was available to participants, although it was not utilized. Participant 1 logged into the program 26 times and completed the program in just over 6 weeks. Participant 2 logged in 35 times and completed the program in 4 weeks.

The primary outcome measure, %SS, was obtained from two unscheduled telephone calls. One of the phone calls was a 'routine' call in which participants selected their own topic. The other phone call was a 'challenging' phone call for which the participant was asked to comment on a controversial topic of the caller's choosing. The calls also differed in the manner the caller conversed with the participant. For the routine call, the caller listened to and acknowledged the participant's speech. For the challenging call the caller interrupted, spoke over and disagreed with the participant a predetermined number of times. From pre-treatment to post-treatment, both participants' stuttering frequency decreased. Participant 1

demonstrated a reduction in %SS scores of 61% for the routine call and 57% for the challenging call. Participant 2 demonstrated a reduction in stuttering frequency of 79% for the routine call 42% for the challenging call. Exact values for %SS were not reported for pre- and post-treatment measures; however, approximate values can be read from figure 1 (p. 212 [38]). Secondary outcome measures – self-rated stuttering severity, avoidance of speaking situations and impact of stuttering – all improved from pretreatment to post-treatment for both participants.

While computer-based treatments for stuttering are in the early stages of development, this study does demonstrate the potential of an Internet-delivered computer program to reduce stuttering frequency and improve self-reported stuttering severity scores, quality of life and engagement in some adults [38]. The results of future research of revised and improved versions of Internet-driven computer programs for the treatment of stuttering are eagerly awaited.

Discussion

Telehealth Models of Stuttering Management

The available evidence to date documents the use of telephone, dedicated videoconferencing sites, home-based videoconferencing programs with personal computers and webcams, and Internet-driven computer treatment programs for stuttering management. The application of the telephone for telehealth delivery of stuttering treatment in the studies reviewed [15, 17, 19, 29, 31], while considered low-tech, was a viable telehealth delivery option due to the constraints of infrastructure in Australia at the time. The delivery of telephone treatment is convenient for speech-language pathologist and client, cost-effective, and eliminates the need for client travel to clinical sites. The telephone is a reliable standby alternative in the event of equipment failure or service interruptions, for example, when using dedicated videoconferencing facilities and personal computer-based Internet-driven modalities. Even at the time of this review, the telephone system continues to be cost-effective, reliable and portable.

With videoconferencing, client and speech-language pathologist are able to see each other, which may facilitate rapport. The speech-language pathologist can observe clients, and in the case of stuttering, monitor subtle behaviors and covert stuttering. For the treatment of young children who stutter, the advantage is that the speech-language pathologist can observe the parent or caregiver demonstrat-

ing treatment and provide direct and immediate feedback. Dedicated videoconferencing sites require less infrastructure than large clinical sites. However, such setups can be costly to establish and require ongoing maintenance and technical as well as logistical support. While rural or remote clients may gain access to specialist services as well as the convenience of reduced travel cost and time, this mode does not obviate the client's need to travel to a central site.

It would be anticipated that, worldwide, technological improvements to Internet bandwidth will continue to increase the viability of home-based videoconferencing treatment using the Internet. For example, in Australia, the National Broadband Network is anticipated to reach one third of Australian homes and businesses by mid-2015 [39]. The development of secure home-based Internet videoconferencing systems is a promising possibility; however, such systems would also need to take into account individual hardware variability. The Internet is subject to interruptions due to infrastructure breakdowns, and high traffic and peak usage times, which can slow or interrupt connections. Internet provider plans and download limits can vary and Internet service providers may slow or terminate connections when download limits have been reached or exceeded. However, ethical and privacy issues need to be considered with the use of free online videoconferencing software programs [40].

In terms of telehealth stuttering management, it is probably unrealistic to expect that every client of every age would be managed effectively with videoconferencing or home-based Internet webcam intervention. Client selection for telehealth will need to take into consideration individual client characteristics, lifestyle and location, general household and financial circumstances, as well as the availability of technology and infrastructure. Even allowing for socioeconomic factors that might prevent Internet access, it is likely that some clients will have needs that can be fulfilled only by a speech-language pathologist in-person in a clinic setting. For instance, those clients with concomitant disorders or complex communication needs [4].

Internet-driven computer programs offer the potential for clients to access treatment or to refresh their skills as needed at any time. While such programs require further development and evaluation, perhaps clinical research will determine that standalone Internet treatments that do not require a speech-language pathologist will be the first intervention of a stepped care model. A stepped care approach involves the provision of less intensive treatments, in terms of economic and personal cost and the extent of direct specialist time required, in the first

instance, and then increasing to more intensive treatment options as needed. In this model client progress and results are monitored and changes are made if improvements or gains are not being demonstrated. This process involving clients progressively escalating to more complex and expensive health care models as they are needed is termed 'stepping up' [41].

Additionally, speech-language pathologists might integrate online programs to support treatment or maintenance [42]. For example, a client might complete computer-based training to learn the prolonged speech technique and then complete treatment in-clinic with the speech-language pathologist. Clients might also use computer-based programs for ongoing practice or to refresh their skills over time.

Evidence for Telehealth Stuttering Management

Efficiency of Telehealth Stuttering Management

A feature of the telehealth stuttering intervention literature reviewed is that with both low-tech telephone methods and also with home-based Internet methods for adult stuttering treatments, there is reason to believe that telehealth speech restructuring treatment with adults and adolescents may require fewer speech-language pathologist hours than in-clinic treatment. Equally interesting, however, is that the situation seems to be reversed with the treatment of young children. The telehealth applications for early stuttering intervention appear to require far more clinical hours than in-clinic treatment. A possible reason for this situation may be that speech-restructuring treatment for chronic stuttering involves direct instruction to the client; however, the treatment is less direct in the case of early stuttering intervention with the Lidcombe Program. In the latter case, the speech-language pathologist teaches the caregiver how to do the treatment procedures, typically by demonstration and then providing feedback about their performance. An increased reliance on verbal instructions in the absence of direct and relevant demonstrations might account for some of the observed decreases in efficiency with telehealth treatment for young children.

Telehealth Assessment of Stuttering

A striking feature of the body of telehealth stuttering treatment research so far is that it is entirely unsupported by basic research about assessment methods. In contrast to a range of basic research about assessing child and adult speech and language disorders with telehealth [for

a recent review, see 6], not a single study has verified the viability of telehealth stuttering assessment with clients of any age. These include, but are not constrained to, verification that a speech-language pathologist, using a webcam, is able to consistently and accurately identify stuttering behaviors.

It is now obvious, from the high rates of anxiety-related psychiatric illness associated with chronic stuttering [for a review, see 37], that comprehensive assessment is needed in order to determine whether anxiolytic intervention is required along with, or without, speech rehabilitation. Such assessment involves screening during interview and administration of pertinent diagnostic tests. Speech-language pathologists need guidance from basic research to know whether such screening and assessment of adolescents and adults by telehealth produces the same results as in the clinic.

Telehealth Stuttering Management with School-Age Children and Adolescents

There is currently very little research investigating the application of telehealth to the management of school-age children and adolescents who stutter. The two studies that did include school-age children and adolescents reported on small participant numbers and one lacked details for replication [21, 34]. The school-age and adolescent populations already have limited treatment options due to a lack of community health services and specialist speech-language pathologists with the necessary expertise and experience. During the school-age and adolescent years, increasing demands from school and extracurricular activities, family lifestyles and work commitments make accessing those limited services difficult. Using telehealth for the management of this stuttering population can allow access to specialist speech-language pathologists, as well as offering convenience to families of children who stutter. Adolescents may be particularly suited to this mode of delivery as they have grown up using technology as part of their daily lives, for example, school work, gaming, and socializing [36, 43]. Additionally, adolescence is a time during which independence is sought and the use of telehealth for stuttering management may increase compliance and motivation [36].

Cost-Benefit and Economic Analysis of Telehealth Stuttering Management

To our knowledge, the economic health benefits of telehealth stuttering treatment are currently unknown, and nor is there an established or consistent method for evaluation available. This is a complex area that requires

specific research questions and studies designed accordingly [44]. The challenge of translating evidence from research into routine clinical practice will persist until such time that information from cost-benefit and economic analyses is available [11].

Ethical and Legal Considerations

Despite the obvious benefits of telehealth services in general, there are also considerable ethical and legal issues to consider. Duty of care, the legal aspects of telehealth, and therefore professional indemnity insurance may differ between telehealth and standard treatment formats [45]. For instance, each state of the United States has a separate licensure board, presenting a barrier to service provision across states [4, 45]. The legal and ethical obligations with the provision of services across international borders are yet to be resolved. Telehealth treatment also makes it a more comprehensive task to satisfy the ethical requirement of informed consent for all procedures. Importantly it is essential that speech-language pathologists have a sound awareness of privacy issues that arise with using telecommunications systems in order to satisfy professional ethics requirements [46]. Even at the time of writing, the ethical use of Internet-based videoconferencing programs such as Skype remains unresolved. The commercial owner of Skype is reportedly able to retain text messaging associated with the program, although it does not – but could well – obtain audiovisual records of telehealth treatment sessions [40, 47]. Additionally, the extent to which the Skype model may be trusted for health interactions and medicolegal aspects with regard to the provider or client recording and subsequently sharing recorded sessions is also questioned [40].

Professional Standards for Telehealth Stuttering Management

There is a critical need for development of professional guidelines and technical standards for stuttering management with telehealth. Highlighted as a barrier to the uptake of telehealth, the establishment of such guidelines will ensure that telehealth stuttering management is not inferior to the standard of care provided with traditional in-clinic services [11].

Future Research

Within the field of speech-language pathology treatment research, there is not universal agreement that randomized controlled trials should be accepted as the

gold standard. Some have offered the view that single-subject experimental designs are more appropriate for the profession's treatment efficacy research [48, 49]. Bothe et al. [48] suggest that reliance on statistically significant methods for interpreting randomized controlled trials may override clinical significance and what they term personal significance. Nevertheless, the existing barriers to the uptake of telehealth practices by speech-language pathologists for stuttering management and speech-language pathology intervention in general, including a lack of professional standards and guidelines, lack of evidence of efficacy, efficiency and cost-effectiveness, will be overcome by high-quality evidence-based research [11].

Telehealth Assessment of Stuttering

A critical research focus is to determine the reliability of assessment procedures for diagnosis of stuttering. Evidence from research is needed to identify and guide service providers on optimal compatibility, network speeds and types of connections to ensure the assessment of stuttering with telehealth is reliable and comparable to traditional in-clinic methods [40]. Such evidence will guide the development of assessment protocols using telehealth applications.

Telehealth Treatment Outcomes

Outcomes from telehealth interventions need to be compared with traditional in-clinic stuttering interventions. As well as investigating clinical outcomes, research needs to continue to focus on the assessment of client satisfaction with the delivery model [10]. Research is needed to continue to explore telehealth intervention with the full range of client groups. In particular, further research exploring telehealth intervention is needed with school-aged children and adolescents who stutter of which little research has been conducted to date. Evidence from research is required to identify those factors that may predict responsiveness to telehealth applications of stuttering interventions for example, stuttering severity and stimulability [20, 42].

Efficiency of Telehealth Stuttering Management

In the case of managing preschool-aged children who stutter, it is necessary to continue to explore ways to improve the efficiency of telehealth methods. Advances in the availability of technology, for example home-based videoconferencing, enable the speech-language pathologist to observe and provide direct feedback to the caregiver in real time [20, 28]. Further development and eval-

uation of such methods is necessary. Preliminary evidence has shown that this method may still not meet current benchmarks for standard delivery. Evidence from clinical trials is needed to compare the efficiency of telehealth adaptations of treatments for young children who stutter as well as comparing these methods with traditional in-clinic procedures.

Computer-Based Treatment Programs

It will be important to further develop and evaluate purpose-built computer programs for people who stutter. Program development could extend to all age groups. It is not unrealistic, in the case of young children who stutter, that such programs would train caregivers to conduct the treatment with their child as a speech-language pathologist would with traditional administration of the Lidcombe Program. Again, this could represent one step within a stepped care approach. For example, following computer-based training, families might then commence in-clinic consultations with a speech-language pathologist to complete the next phase of treatment. In another scenario, a caregiver undergoing computer-based training might request a consultation with a speech-language pathologist if improvements in the child's speech were not meeting benchmarks associated with standard treatment procedures. Computer-based stuttering treatment programs might also be suited to school-aged and, in particular, adolescent clients.

Availability of Technology

Research needs to take into consideration the type of technology and infrastructure available to service providers and clients. In their review, Mashima and Doarn [11] foreshadowed the future development of secure personal computer-based videoconferencing from client's homes. To date, this possibility has been realized by way of free downloadable applications such as Skype. However, the security and privacy of such applications are uncertain. With an age of evidence-based, home-based, webcam Internet stuttering management about to begin, we urgently require research to determine some fundamental issues. The development of alternative systems that are cost-effective and offer ease of use and compatibility as well as conforming to privacy and security regulations is one possible solution. Smartphones and electronic tablet technology is another avenue to explore the possibilities for stuttering management, offering real-time client and speech-language pathologist interactions as well as applications and programs that can support stuttering interventions.

Cost-Benefit and Economic Analysis of Telehealth Stuttering Management

Cost-benefit and economic analyses of telehealth applications to stuttering management are needed. Without such evidence, the uptake of telehealth service delivery will continue to be hindered. The focus should extend beyond that of efficacy, efficiency, infrastructure, and the cost of such technology, to include an analysis of the overall cost to the healthcare system [44]. In order to conduct such analyses, evidence from both the short- and long-term effects of telehealth is essential [44]. Consideration to the negative effects of long-term stuttering is necessary when interpreting the results of such analyses.

Professional Standards for Telehealth Stuttering Management

For the management of stuttering there is a critical need for professional guidelines and clinical protocols, as well as technical standards such as equipment specifications. As highlighted in previous reviews, evidence from research evaluating clinical processes will guide this development [10, 11].

Conclusion

This review has provided a detailed overview of the literature available for the application of telehealth to stuttering management. There is no doubt about the potential contribution of telehealth to assessment and treatment of stuttering, with a list of advantages over in-clinic treatment that seem compelling. That being said, the efficacy and reliability regarding the assessment of stuttering across the age groups is currently unknown. No research has comprehensively evaluated the cost-benefit or economic health benefits of stuttering interventions using telehealth modalities. It is clear that there is need for vigorous research in this area to refine procedures and improve efficiency, particularly for young children who stutter. Importantly there is the need for the development of clinical guidelines and technical standards to ensure that standards of care and service delivery with telehealth are not inferior to traditional in-clinic models.

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Appendix

Summary of Studies for Telehealth Management of Stuttering

Study	Year	n	Age	Study design	Technology	Treatment	Results	Conclusion
Harrison et al. [15]	1999	1	5 years 10 months	Case study	Telephone	Modified Lidcombe Program	Stuttering frequency Pre-treatment (mean of 3 samples) 15%SS 23 months post-treatment below 1.0%SS Number of consultations to Stage 2 (maintenance) 25	Feasible to administer the Lidcombe Program using the telephone Greater number of consultations required than standard in-clinic delivery
Kully [33]	2000	1	Adult	Case report	Dedicated site-based videoconferencing	Follow-up program after a 3-week intensive treatment program	Informal evaluation Participant satisfied with 'structure of the session and the effectiveness of the feedback' SLP satisfied with sound and visual quality permitting 'accurate judgments about most aspects of the patient's speech performance'	Videoconferencing feasible for delivery of follow-up services
Kully [20]	2002	Not stated	3 – 38 years	Anecdotal report	Dedicated site-based videoconferencing Combination of in-clinic and telehealth One 10-year-old client received treatment entirely using telehealth	Lidcombe Program Comprehensive Stuttering Program	Informal evaluation Treatment goals achieved Clients satisfied with telehealth intervention Clients preferred telehealth sessions to traveling long distances	Telehealth feasible with children and adults Setup costly The need for clients to travel to dedicated sites
Sicotte et al. [21]	2003	6	3 – 12 years, 17 and 19 years	Phase I study	Dedicated site-based videoconferencing	Not specified 12 one-hour sessions (2 participants) 20 one-hour sessions (4 participants)	Stuttering frequency Pre-treatment (range) 13 – 36%SS Post-treatment (range) 2 – 26%SS End of follow-up (range) 4 – 32%SS Reduction in stuttering frequency 48% post-treatment 46% at end of follow-up Participants highly satisfied with technical and clinical aspects of telehealth delivery SLP mostly satisfied with technical and clinical aspects of telehealth delivery	Site-based videoconferencing feasible Modest reductions in stuttering frequency

Appendix (continued)

Study	Year	n	Age	Study design	Technology	Treatment	Results	Conclusion
Wilson et al. [17]	2004	5	3 years to 5 years 5 months to 7 months	Phase I study Series of case studies	Telephone	Modified Lidcombe Program	Stuttering frequency (range) Pre-treatment 2–20%SS 12 months post-treatment 2 participants <1.0%SS 2 participants <2.0%SS Data unavailable for 1 child 22 (range 3–34) Parents satisfied with materials and processes of telehealth delivery	Telephone administration of Lidcombe Program viable and effective Greater number of consultations required than standard in-clinic delivery High withdrawal rate. Four families who withdrew indicated unwillingness to comply with telehealth treatment requirements, e.g. making frequent recordings of child's speech; implications of requirements for low-tech telephone delivery of Lidcombe Program
Lewis et al. [19]	2008	22	3–6 years	Phase II randomized control study	Telephone	Modified Lidcombe Program – Telehealth Lidcombe Program (9 participants) – Notreatment control group (13 participants)	Stuttering frequency (mean) Randomization 6.7%SS (telehealth) 4.5%SS (control) 9 months post randomization 1.1%SS (telehealth, n=8) 1.9%SS (control, n=10) Responders 6 (telehealth, n=8) 2 (control, n=10) Reduction in stuttering frequency from randomization to 9 months post randomization 69% in telehealth group compared with control Number of consultations to Stage 2 (mean) 49 (range 27–98) Parents satisfied with telehealth treatment and outcomes	Telephone administration of Lidcombe Program viable and effective Greater number of consultations required than standard in-clinic delivery
O'Brian et al. [29]	2008	10	28–48 years	Phase I study	Telephone	Modified Camperdown Program	Stuttering frequency (mean) Pre-treatment 7.2%SS Immediately post-treatment 1.4%SS %SS 6 months post-treatment 1.9%SS Reduction in stuttering frequency from pre-treatment to 6 months post-treatment 74% Typical self-reported stuttering severity (mean) 5 (pre-treatment) 2 (post-treatment) SLP contact hours to maintenance (mean) 8 (range 5.2–16.9)	Telehealth delivery of Camperdown Program effective in reducing stuttering in some adults who stutter Reduced clinical hours compared with in-clinic delivery

Appendix (continued)

Study	Year	n	Age	Study design	Technology	Treatment	Results	Conclusion
Carey et al. [31]	2010	40	Adult	Phase II randomized control study	Telephone	Modified Camperdown Program (20 participants) Standard in-clinic Camperdown Program (20 participants)	Stuttering frequency (mean) Pre-treatment 6.9%SS (telehealth) 5.4%SS (in-clinic) 9 months post randomization 3.0%SS (telehealth) 2.7%SS (in-clinic) Daily self-reported stuttering severity (mean) Telehealth 3.9 (pre-treatment) 2.3 (9 months post-randomization) In-clinic 3.8 (pre-treatment) 2.4 (9 months post-randomization) SLP contact hours to complete treatment (mean) 10 h 17 min (telehealth) 12 h 54 min (in-clinic) Telehealth described by participants as convenient	Telephone delivery of Camperdown Program as efficacious as in-clinic delivery Telehealth significantly more efficient than standard in-clinic A viable alternative to standard in-clinic delivery
Carey et al. [34]	2012	3	13, 15 and 16 years of age	Phase I study	Home-based videoconferencing using personal computers and webcams	Modified Camperdown Program	Stuttering frequency pre-treatment to post-treatment (mean) 16.7%SS (P1) to 8.4%SS (P1) 21.8%SS (P2) to 2.5%SS (P2) 9.2%SS (P3) to 1.6%SS (P3) Reduction in stuttering frequency (group mean) 83% (entry to maintenance) 93% (6 months post entry to maintenance) 74% (12 months post entry to maintenance) Typical self-reported stuttering severity (mean) Pre-treatment 4.9 Post entry to maintenance 1.9 SLP contact hours to maintenance (mean) 11 h (range 8 h 18 min–15 h) Situation avoidance scores Large reduction (P1) Small and inconsistent change (P1 and P2) Treatment satisfaction Parent: easy and convenient Adolescent: helpful and comfortable	Home-based videoconferencing using personal computers and webcams efficacious, efficient and appealing Further investigation regarding absence of reduction in situation avoidance following treatment warranted

Appendix (continued)

Study	Year	n	Age	Study design	Technology	Treatment	Results	Conclusion
Erickson et al. [38]	2012	2	Adult	Phase I study	Internet-driven computer program	Computerized adaptation of Camperdown Program	Reduction in stuttering frequency for 2 outcome phone calls 61 and 57% (P1) 79 and 42% (P2) Typical self-reported stuttering severity (mean) P1 7 (pre-treatment) 5.1 (post-treatment) P2 6 (pre-treatment) 1.4 (post-treatment) Treatment time 6 weeks, 26 logins (P1) 4 weeks, 35 logins (P2) Reduction in avoidance and impact of stuttering scores for both participants	Potential for computer-based treatment program to reduce frequency of stuttering Requires further development and evaluation
O'Brian et al. [28]	in press	3	3 years 6 months 4 years 3 months 4 years 9 months	Phase I study	Home-based videoconferencing using personal computers and webcams	Modified Lidcombe Program	Stuttering frequency Pre-treatment 3.7%SS (P1) 4.1%SS (P2) 2.6%SS (P3) 6 months post entry to Stage 2 less than 1.0%SS (all 3 participants) Reduction in stuttering frequency 81% (P1) 99% (P2) 69% (P3) Number of consultations to complete Stage 1 (mean) 34 (range 26–39) Parents positive about webcam delivery of treatment	Home-based webcam delivery of Lidcombe Program efficacious Mean of 34 treatment sessions higher than in-clinic benchmarks

SLP = Speech-language pathologist.

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