

Stuttering Treatment Approaches from the Past Two Decades: Comprehensive Survey and Review

Garima Gupta^{1*}, Shruti Chandra^{1*}, Kerstin Dautenhahn^{1#}, and Torrey Loucks^{2#}

¹University of Waterloo, ON, Canada

²University of Alberta, Canada

#Advisor

*Equal contribution to this submission

ABSTRACT

This comprehensive survey and review presents stuttering treatment approaches that have been reported in the past 20 years in order to highlight the different characteristics in each intervention. The comprehensive survey presented in this article was conducted according to the PRISMA guidelines to extract articles on stuttering interventions, published between 01/01/2000 and 01/08/2020. 11 formal programs, 9 fluency induction techniques and 7 adjunct therapy approaches were identified through the comprehensive survey and summarized. The most common results were the Lidcombe program and altered auditory feedback techniques. The comprehensive survey and review presented in this article strives to provide knowledge that can help researchers in other areas, such as Human-Robot Interaction (HRI), acquire a preliminary understanding of stuttering interventions and further the field of stuttering interventions with the introduction of technological advancements.

Introduction

Stuttering is a disorder in which the individual knows what they intend to say, but their articulation is disrupted by involuntary repetition of sounds, syllables, or words; prolongation of sounds; and pauses or blocks (Guitar, 2013; Prasse & Kikano, 2008). These primary symptoms of stuttering are typically accompanied by physical (e.g., involuntary eye-blinking, jaw jerking) and/or affective (e.g., avoidance behaviours, negative emotions) secondary behaviours (Guitar, 2013; Prasse & Kikano, 2008). Stuttering is typically classified into broad categories of developmental vs. acquired and chronic vs. recovery (Büchel & Sommer, 2004; Prasse & Kikano, 2008). Developmental stuttering manifests in early childhood, whereas, acquired stuttering has an onset during adulthood. Acquired stuttering tied to neurological or psychological trauma (Krishnan & Tiwari, 2013; Theys et al., 2008). Age of onset for developmental stuttering is between the ages of two to six (Büchel & Sommer, 2004). There is variation in the prognosis of this developmental form, such that some children naturally recover from stuttering, whereas for others stuttering becomes chronic and persists throughout their lives (Büchel & Sommer, 2004). A review of 44 studies with school-aged children from across the world reported 1% prevalence rate for stuttering (Bloostein & Bernstein Ratner, 2008). Stuttering is more prevalent in males than females, with a sex ratio being 4:1 males-to-females (Craig et al., 2002). Sex-based prevalence is smaller among preschool children, with the sex ration being 2:1 males-to-females (Craig et al., 2002; Yairi et al., 2005; Yairi & Ambrose, 2013).

The disruptive effects of stuttering on speech communication are associated with negative impact on the quality of life of individuals who stutter (Group et al., 1995). Difficulties associated with stuttering go beyond the primary speech dysfluencies and extend to social, emotional and psychological problems that impact important life choices, including vocation (Bloostein & Bernstein Ratner, 2008; Craig et al., 2009; Craig-McQuaide et al., 2014; Langevin & Bortnick, 1998; Linn & Caruso, 1998; Manning, 1999; R. G. Menzies et al., 1999; Shears & Jensema, 1969; Silverman & Paynter, 1990 Yaruss, 2010). While there is no cure for stuttering, there are a variety of treatments

that strive to enhance fluency and reduce the disruptive effects of stuttering on other areas of life.

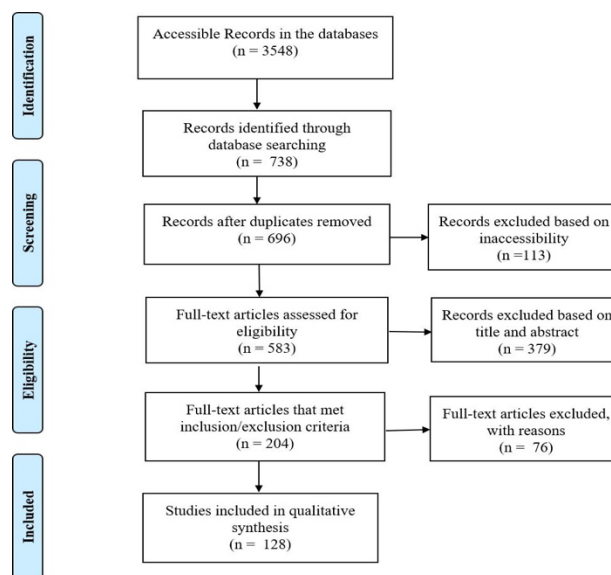
This comprehensive survey outlines the behavioural treatment approaches for stuttering that have been reported in the past two decades (2000-2020). Although the procedures for a systematic review were followed to identify the treatment approaches, we acknowledge that the review may not be exhaustive. The review does not entail evaluation of the identified interventions. Recent systematic reviews, such as those by Baxter et al. (2015), Baxter et al. (2016), Brignell et al. (2020), and Connery et al. (2020), Johnson et al. (2016) consider the efficacy of a subset of the behavioural interventions identified in this comprehensive survey. Information pertaining to the effectiveness of the listed interventions can be retrieved from such systematic reviews. Our review differs in that a broad swath of the field over 20 years was covered to identify comprehensively the diversity of treatment approaches reported from 2000-2020.

The present article is organized in three sections. Section 1 of the article outlines the procedure and the general results of the comprehensive survey of stuttering interventions. Section 2 provides identifies and describes behavioural interventions for stuttering reported in the past two decades. Section 3 ties up-and-coming technologies, such as artificial intelligence, to conventional stuttering interventions. This article concludes with a summary of the comprehensive survey, and its limitations and contributions to research in stuttering.

Comprehensive Survey Procedure

Protocol & Information Sources

This comprehensive survey of stuttering interventions followed the PRISMA guidelines established for systematic reviews. The search was completed in two major databases, ASHA (June 2020) and PubMed (August 2020), as well as the Google scholar (May 2020) search engine. The selected databases were used due to their relevance to the subject of stuttering and their reliability. For example, ASHA (American Speech -Language-Hearing Association)



primarily covers publications pertinent to communication disorders.

Figure 1. Systematic selection of research articles for the comprehensive survey.

Search parameters

Since different databases require different formats for search queries, we used separate queries for each database to identify the relevant papers. Nonetheless, each query was composed of the following terms: Stuttering, stammering, fluency, disfluency, intervention, treatment, therapy.

Article selection

Published articles that were identified focused on behavioural treatments for stuttering that have been used in the past two decades and/or are currently being used. Articles were included based on the following inclusion and exclusion criteria.

Inclusion Criteria

All the articles were required to be peer reviewed journal publications, case reports, surveys, clinical trials with qualitative and/or quantitative results. Only articles in English were included. Only articles with behavioural interventions and other non-invasive, non-pharmacological treatments for developmental and acquire stuttering were included. There was no restriction on age of participants and setting of treatment delivery.

Exclusion criteria

One-two page abstracts, workshop and discussion papers, reviews and articles without any quantitative and/or qualitative results were excluded. Articles with pharmacological or surgical interventions and/or comorbid neurodevelopmental, language or hearing impairments were excluded. Articles related to the fluency disorder known as cluttering were also excluded.

General Results

The aforementioned inclusion and exclusion criteria narrowed the search results from 3548 to 128 articles (Figure 1). The selected articles discussed 27 different behavioural approaches, of which 11 are formal treatment programs, 9 support fluency induction, and 7 are adjuncts to treatment. As shown in Figure 2, among the 11 formal programs, the Lidcombe Program was the most frequent with a total of 32 results. The Camperdown Program (7), and the Comprehensive Stuttering Program (6) ranked were the second and third most frequently discussed programs, respectively, see Figure 3. Figure 4 shows the 9 fluency induction techniques, among which altered auditory feedback (AAF) was the most frequent with a total of 26 results. Choral reading (8), and syllable-timed speech (7) were the second and third most frequent, respectively, see Figure 4. Finally, cognitive behavioural therapy (CBT) was the most frequent adjunct technique with 7 results as shown in Figure 5.

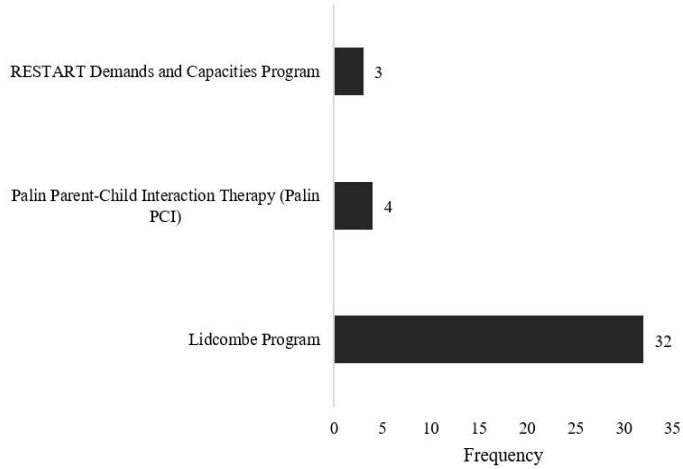


Figure 2. Stuttering treatment Programs identified for pre-school children.

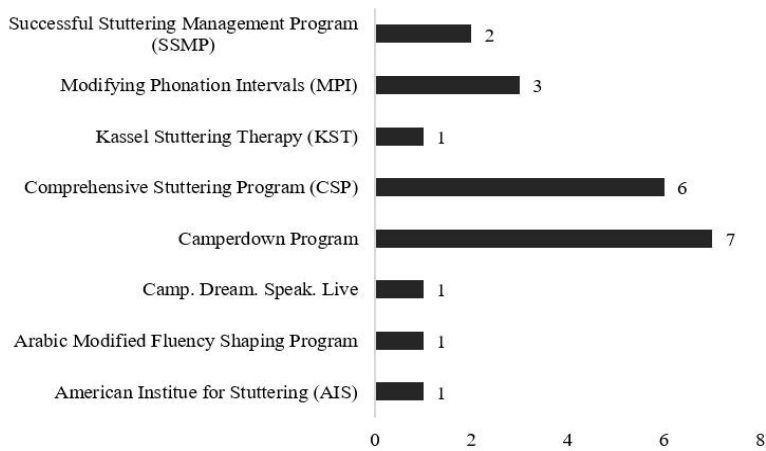


Figure 3. Stuttering treatment Programs identified for school-age children, adolescents and adults.

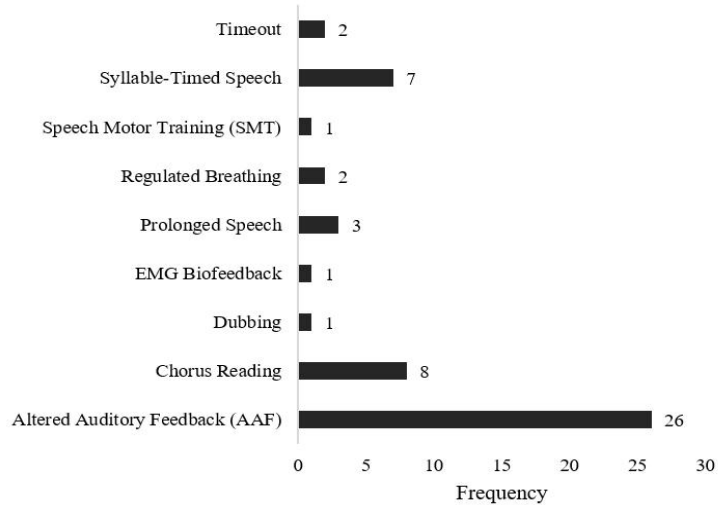


Figure 4. Identified stuttering treatment techniques for fluency induction.

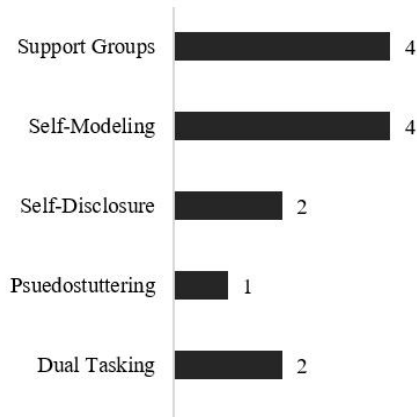


Figure 5. Identified adjunct stuttering therapy approaches.

The comprehensive survey further found that 37% percent of the extracted papers focused on adults (ages 18 to 64 years), 18% on preschool children (6 and under), 17% on adolescents (13 to 17), and 19% specified school-age children (7 to 12). An additional 9% included older adults (65 and over). In regards to gender, most of the extracted studies identified the category of male more frequently than female with a ratio of 2.5:1. In regards to frequency of reported nationality, 45 extracted papers (approximately 35% of the total extracted papers) studied Australians and 44 papers (approximately 34%) studied Americans. Canada (10), The Netherlands (7) and United Kingdom (6) were the three others frequently appearing participant nationalities. Approximately 1-4 studies were found for participants from other countries including: Iran (4), Germany (3), New Zealand (3), China (2), India (2), Israel (2), Nigeria (2), Austria (1), Belgium (1), Brazil (1), Bulgaria (1), Croatia (1), Denmark (1), Egypt (1), Finland (1), France (1), Indonesia (1), Italy (1), Malaysia (1), Pakistan (1), Poland (1), Singapore (1), South Africa (1), Spain (1), and Sweden (1).

Behavioural Interventions for Stuttering

Behavioural interventions for stuttering include programs and techniques that strive to reduce stuttering severity and the frequency of stuttering symptoms or to teach new speech skills that emphasize fluency and naturalness (Hewat et al., 2006; Nye et al., 2013). Behavioural interventions for stuttering can be segregated into categories based on population (Blomgren, 2013). For pre-school children, the interventions are either direct or indirect, while for school-age children, adolescents and adults, the interventions primarily focus on fluency shaping or stuttering modification (Blomgren, 2013; Brignell et al., 2020). Most interventions for stuttering incorporate the principles of operant conditioning, which is “the process by which the frequency of a response is changed as a result of the consequences of that response” (Nittrouer & Cheney, 1984). It has been integrated in numerous interventions (e.g., Lidcombe Program) and fluency induction techniques (e.g., time-out) (Nittrouer & Cheney, 1984; Onslow et al., 2001; P. Reed & Howell, 2000; Sidavi & Fabus, 2010). Positive or negative reinforcement are implemented in these response-contingent approaches to increase or decrease the frequency of a response. Typically, positive reinforcement, which entails introduction of a desirable stimulus, and negative reinforcement, which includes removal of an undesirable stimulus, increase the frequency of a response (Nittrouer & Cheney, 1984). Research has shown that operant conditioning can decrease the frequency of stuttering to near zero levels (R. R. Martin et al., 1972; Onslow et al., 1990; C. G. Reed & Godden, 1977; Sidavi & Fabus, 2010). Within recent stuttering treatments such as the Lidcombe Program (see below), positive has been incorporated. In most treatments, positive reinforcement is more emphasized than negative reinforcement because studies have shown that stutter-free speech can be achieved without negative verbal contingencies (Donaghy et al., 2015; Swift et al., 2016).

Stuttering Intervention Categories

Category 1: Direct vs. Indirect Treatments

This category of intervention applies to children (Blomgren, 2013). Direct interventions focus on explicitly altering the child’s speech to improve fluency (Blomgren, 2013; de Sonnevile-Koedoot, Stolk, et al., 2015; Frymark et al., 2010) through approaches that can include fluency shaping and stuttering modification described below (Frymark et al., 2010; Nippold, 2018). Direct treatments are delivered by the clinician or parent(s) trained by the clinician. In contrast, indirect treatments promote fluency by decreasing environmental or internal demands on the child (Blomgren, 2013; de Sonnevile-Koedoot, Bouwmans, et al., 2015; de Sonnevile-Koedoot, Stolk, et al., 2015; Frymark et al., 2010). For example, training the parent to alter their own speech and behaviour to facilitate fluency in the child’ speech (Frymark et al., 2010).

Category 2: Fluency Shaping and Stuttering Modification Treatments

Fluency shaping interventions, also called speech modification, speech restructuring or prolonged speech treatments, strive to promote speech fluency by teaching new speech patterns to the client (Alpermann et al., 2012; Blomgren, 2010; Nye et al., 2013). Examples of fluency enhancing techniques include stretched syllables, controlled rate, or slow speech (Blomgren, 2010, 2013). In contrast, stuttering modification treatments are focused on cognitive and anxiolytic (i.e., anxiety-related) issues to promote acceptance and reduce fear or anxiety of stuttering, while teaching the client to stutter with decreased effort (Blomgren, 2010, 2012, 2013). Some examples of stuttering modification techniques include self-disclosure of stuttering, voluntary stuttering and ceasing avoidance behaviours (Blomgren, 2010).

In the following section, we offer brief summaries of the specific therapy programs, treatment approaches and fluency inducing techniques that were identified in our survey of interventions reported between 2000 and 2020 (see Table 1). It should be noted that the list of treatment programs, approaches and techniques are based on the frequency of reporting in the clinical literature, not on efficacy or popularity. Further, a large number of programs and approaches were identified, but not all could be described here, such as the Arabic Modified Fluency Shaping Program (Rifaie et al., 2016), Camp. Dream. Speak. Live. and Acceptance and Commitment Therapy (ACT) are more recently developed intervention programs that show therapeutic potential, but are not described further in order to manage the length of the review (Beilby et al., 2012; Byrd et al., 2018; Freud et al., 2020). Several less common stuttering intervention techniques were identified that are also not described below, including (1) Dual Tasking (Metten et al., 2011; Nejati et al., 2013), (2) Dubbing (Tomaiuli et al., 2006), (3) EMG Biofeedback (Block et al., 2004), and (4) Speech Motor Training (SMT) (Riley & Ingham, 2000). Figures 4 and 7 provide an overview of the frequency of the identified programs and techniques.

Table 1. Categorization of stuttering treatment programs and techniques identified between 2000 and 2020 according to intervention categories and target population.

Formal Treatment Programs	Category	Target Population
American Institute for Stuttering	Integrated	Adults
Camperdown Program	Fluency Shaping	School-age children, adolescents and adults

Comprehensive Stuttering Program (CSP)	Integrated	School-age children, adolescents and adults
Kassel Stuttering Therapy (KST)	Fluency Shaping	Adults
Lidcombe Program	Direct	Pre-school children
Modifying Phonation Intervals (MPI)	Fluency Shaping	Adults
Palin Parent-Child Interaction Therapy (Palin PCI)	Indirect	Pre-school children
RESTART Demands and Capacities Program	Indirect	Pre-school children
Successful Stuttering Management Program (SSMP)	Stuttering Modification	Adolescents and adults
Fluency Induction/Treatment Adjuncts	Category	Target Population
Altered Auditory Feedback (AAF)	Fluency Shaping	School-age children, adolescents and adults
Choral Reading	Fluency Shaping	Adolescents and adults
Cognitive Behavioural Therapy (CBT) Techniques	Stuttering Modification and Integrated	Adolescents and adults
Prolonged Speech	Fluency Shaping	School-age children, adolescents and adults
Pseudostuttering	Stuttering Modification	Adolescents and adults
Regulated Breathing	Fluency Shaping	Adolescents and adults
Self-Disclosure	Stuttering Modification	Adults
Self-Modeling	Stuttering Modification	School-age children, adolescents and adults
Support Groups	All categories	
Syllable-Timed Speech	Fluency Shaping	School-age children, adolescents and adults
Time-Out	Operant Conditioning	Adolescents and adults

Therapy Programs

Programs for Pre-school Children

Lidcombe Program: Developed at the University of Sydney, Australia, this operant conditioning treatment program is for preschool children, under the age of 6 years (Guitar et al., 2015; Jones et al., 2000; Jones et al., 2005; Onslow et al., 2001). The Lidcombe program is administered by a parent or guardian in the child’s routine environment (Jones et al., 2005; Miller & Guitar, 2009; Onslow et al., 2001; Unicomb et al., 2017). This program has two stages. In stage 1, the caregivers are trained in delivering feedback and positive reinforcement appropriately to the child and monitoring the child’s stuttering (Jones et al., 2000; Lattermann et al., 2008; Onslow et al., 2001). Throughout stage 1, parents provide the treatment and monitor the child’s progress (Lattermann et al., 2008). In stage 2, maintenance of fluency is the primary goal in this stage, and involves gradual reduction in both clinic visits and positive reinforcements. Extensive research indicate children achieved low stuttering levels after the Lidcombe program and maintained these gains for 2 to 7 years after the treatment (Arnott et al., 2014; Jones et al., 2005; Kingston et al., 2003; Lattermann et al., 2008; McCulloch et al., 2017; Miller & Guitar, 2009; Rousseau et al., 2002; Vong et al., 2016).

Palin Parent-Child Interaction Therapy (Palin PCI): This therapy program involves both parent(s) and child (under 7 years) (Millard et al., 2018). The program aims to build the child’s fluency and confidence as a communicator, while

empowering parent(s) to manage their child's stuttering (Millard et al., 2008; Millard et al., 2018). The program starts with in-clinic sessions, where interaction strategies, such as matching the child's speech rate, reducing language complexity, and turn-taking, are taught to parents (Millard et al., 2018). The parents implement these strategies during a six-week home consolidation period (Millard et al., 2018). Findings suggest that this program can facilitate fluency, improving communicative competence, and reducing parental concerns over their child's stuttering (Millard et al., 2008; Millard et al., 2018).

RESTART-Demands and Capacities Model (DCM) Program: RESTART-DCM is an indirect program, based on the Demands and Capacities Model (DCM), which states that a balance between demands (i.e., motoric, emotional, linguistic and cognitive demands) and capacities (i.e., communication) is essential for fluent speech (de Sonnevile-Koedoot, Stolk, et al., 2015; Franken et al., 2005). The aim of RESTART-DCM is to introduce positive changes to the child's environment and abilities in order to 'match' their communication abilities and, thereby, reduce stuttering (de Sonnevile-Koedoot, Stolk, et al., 2015; Millard et al., 2018). Parents are trained to decrease communicative demands (motoric, emotional, linguistic and/or cognitive) on the children (de Sonnevile-Koedoot, Stolk, et al., 2015). They are also taught to provide their child with 15-minutes of special attention daily to boost the child's speaking confidence (de Sonnevile-Koedoot, Stolk, et al., 2015; Franken et al., 2005). Treatment is gradually decreased depending on the parent's ability to foster a fluency enhancing environment and managing relapse (de Sonnevile-Koedoot, Stolk, et al., 2015). Findings suggest the efficacy of RESTART-DCM program is comparable to the Lidcombe program at 18-months post-treatment mark (de Sonnevile-Koedoot, Bouwmans, et al., 2015; de Sonnevile-Koedoot, Stolk, et al., 2015).

Programs for School-Age Children, Adolescents and Adults

American Institute for Stuttering (AIS) Intensive Therapy Program: This holistic program strives to provide therapy that improves stuttering and psychological management (Pollard, 2012). The primary goals of this program include: (a) acceptance of stuttering, (b) elimination of avoidance behaviours, (c) alteration in emotional and cognitive aspects of stuttering, (d) development of stuttering modification and fluency shaping techniques, and (e) provision of alternatives for continued speech management after the treatment (Pollard, 2012). The goals are accomplished through stuttering modification and speech fluency techniques, such as desensitization, group discussions, and speech restructuring (Pollard, 2012). Although further efficacy research is needed, the preliminary findings suggest that stuttering and social anxiety symptoms were reduced following the treatment (Pollard, 2012).

Camperdown Program: This hierarchical speech restructuring program aims to promote speech fluency in individuals who stutter. There are four stages in this program (Carey et al., 2014; Hearne et al., 2008; O'Brian et al., 2003): (1) Clients learn prolonged speech patterns, without reference to specific target behaviours along with self-evaluation techniques for judging stuttering severity and speech naturalness (Carey et al., 2014; O'Brian et al., 2003); (2) Group sessions in which clients practice natural sounding, stutter-free speech while continuing self-evaluation; (3) clients develop problem solving strategies for generalizing their stutter-free speech and; (4) Clients strive to maintain their treatment gains within and beyond clinic by keeping a stuttering severity rating of 1-2 (1 = no stuttering) and speech naturalness rating 1-3 (1 = extremely natural speech) for three consecutive weeks (Carey et al., 2014; Hearne et al., 2008; O'Brian et al., 2003). Participants who completed the Camperdown program "spoke with minimal stuttering rates up to 12 months after entry into a maintenance program" (O'Brian et al., 2003).

Comprehensive Stuttering Program (CSP): Developed at the Institute of Stuttering Treatment and Research (ISTAR) in Canada, this therapy approach offers various treatment formats including a three-week, intensive stuttering treatment program that addresses speech production and related attitudinal difficulties (W. Huinck & Rietveld, 2007; W. J. Huinck et al., 2006; Langevin et al., 2006; Langevin et al., 2010). There are three phases in this program: (1)

acquisition of fluency and cognitive behavioural skills, (2) transfer of learned skills into non-clinical settings, and (3) maintenance of treatment gains (W. Huinck & Rietveld, 2007). Attitudes and/or avoidance behaviours are addressed using cognitive-behavioural strategies, including graded exposure to anxiety inducing talking situations and modification of ineffective or negative “self-talk” (Langevin et al., 2010). In the transfer stage, the speech goals and the cognitive behavioural strategies are combined while progressing through a hierarchy of difficult talking situations and modifying their ineffective self-talk (Langevin et al., 2010). In the maintenance stage, clients engage in self-practice, attend refresher sessions, and participate in self-help groups (Langevin et al., 2010). The majority of the participants from this program accomplished speech fluency with acceptable speech rates and maintained statistically and clinically significant speech gains and stuttering reductions at a five-year follow-up (Langevin et al., 2010).

Kassel Stuttering Therapy (KST): KST is a modified version of the Precision Fluency Shaping Program (Euler et al., 2014; Giraud et al., 2008; Neumann et al., 2003; Neumann et al., 2005). It is a three-week intensive fluency shaping program with a one to two-year structured maintenance program. This program employs a computer program called speak: gentle, Bioservice Software, developed in Munich, Germany. The computer program provides biofeedback for syllable prolongation, soft voice onset, diaphragmatic breathing and smooth sound transitions (Euler et al., 2014; Giraud et al., 2008; Neumann et al., 2003; Neumann et al., 2005). In the maintenance program, clients monitor their practice on the computer and attend a two-three weekend refresher course (Euler et al., 2014). Research has documented longer-term effects on Kassel Stuttering Therapy (KST) for both objectively assessed speech disfluencies and subjectively assessed speech performance (Euler et al., 2014).

Modifying Phonation Intervals (MPI): The MPI treatment is fundamentally based on software that interfaces with an accelerometer placed on the neck that detects phonation (Ingham et al., 2001; Matthews & Blomgren, 2016). The MPI software displays phonation intervals (PIs) to provide the speaker with auditory and visual (bio)feedback regarding the number of and duration of PIs (Ingham et al., 2015; Matthews & Blomgren, 2016). In the four phases in this program, clients learn to eliminate short PI’s from their speech in the clinic, which induces fluency. Then clients transfer this fluency outside the clinic and learn to maintain fluency over the long-term (Matthews & Blomgren, 2016). The client must reduce the frequency of short PI’s along with maintaining speech naturalness criteria in order to progress through the phases (Ingham et al., 2001; Matthews & Blomgren, 2016). Findings suggest participants achieve low levels of stuttering, increased speech rates and acceptable naturalness (Ingham et al., 2015).

Successful Stuttering Management Program (SSMP): The SSMP is an intensive 3-week residential program (Blomgren et al., 2005; Tsiamtsiouris & Krieger, 2010) that incorporates stuttering modification techniques advocated by Van Riper (1973). The program consists of three phases: (1) confronting stuttering, (2) modifying stuttering, and (3) maintaining fluency (Blomgren et al., 2005). The confrontation phase entails identification of stuttering to modify the client’s attitudes and perceptions. The modification phase uses behavioural techniques to reduce the severity of stuttering moments. The maintenance phase entails practice of the learned stuttering modification strategies outside the clinic. Findings indicate that the SSMP is an anxiolytic treatment but does not produce long term reductions in fluency (Blomgren et al., 2005; Tsiamtsiouris & Krieger, 2010).

Treatment Support

Fluency Induction Techniques

Altered Auditory Feedback (AAF): This is a collective term for techniques that electronically manipulate an individual’s speech signal such that speakers hear a modified version of their own speech (Antipova et al., 2008; Lincoln et al., 2006; Lincoln et al., 2010; Unger et al., 2012). In general, the speaker receives a temporally and/or spectrally altered version of their own production (Hudock & Kalinowski, 2014; Lincoln et al., 2006). The three AAF techniques

are delayed auditory feedback (DAF), frequency altered feedback (FAF) and masked auditory feedback (MAF) (Antipova et al., 2008; Hudock & Kalinowski, 2014; Kiefte & Armson, 2008; Lincoln et al., 2006; Lincoln et al., 2010; Stuart & Kalinowski, 2004; Unger et al., 2012). The most well-known implementation for clinical use is the SpeechEasy, which is a self-contained, in-ear-device resembling a hearing aid. Other commercial AAF devices for clinic or home use are the Fluency Master or The Pocket Speech Lab (Antipova et al., 2008). Numerous clinical and experimental studies with people who stutter have demonstrated the fluency enhancing effects of AAF and promising clinical efficacy of the SpeechEasy (Antipova et al., 2008; Armson & Kiefte, 2008; Armson et al., 2006; Foundas et al., 2013; Gallop & Runyan, 2012; Hudock & Kalinowski, 2014; Lincoln et al., 2010; O'Donnell et al., 2008; Pollard et al., 2009; Ritto et al., 2016; Stuart & Kalinowski, 2004; Unger et al., 2012; Van Borsel et al., 2003).

Choral Reading: In choral reading, two or more individuals read a passage out loud in unison (Dechamma & Maruthy, 2018; Ingham et al., 2006; Kiefte & Armson, 2008; Rami et al., 2005; Saltuklaroglu et al., 2009). The effect of choral speech in reducing stuttering frequency is immediate and pronounced (Dechamma & Maruthy, 2018; Ingham et al., 2006; Kiefte & Armson, 2008; Rami et al., 2005; Saltuklaroglu et al., 2009) as stuttering disfluencies reduce between 90%-100% (Dechamma & Maruthy, 2018; Kiefte & Armson, 2008; Saltuklaroglu et al., 2009). Choral reading also induces speech naturalness and reductions in speech effort (Ingham et al., 2006). Pre-recorded speech can also be used as the “choral partner” for the person who stutters (Saltuklaroglu et al., 2009) but monitoring of stuttering symptoms still requires a human counterpart. Pre-recorded passages for practicing choral speech and playing back the exercise can be implemented easily in social robots.

Prolonged Speech: Slowing speech is a powerful fluency inducing technique and is integral to most speech restructuring therapies (Matthews & Blomgren, 2016). Prolonged speech involves producing elongated speech segments, which readily reduces disfluencies (Matthews & Blomgren, 2016). In the therapy context, clients learn to use a very slow speech rate that supports stutter-free speech (Matthews & Blomgren, 2016). Speaking rate is gradually increased, with the goal of maintaining fluency and improving speech naturalness. Some prolonged speech therapies result in unnatural-sounding speech (Matthews & Blomgren, 2016). The CSP and Camperdown programs implement prolonged speech to achieve fluent speech in the early stages of the program and then shape speech into a more controlled rate with acceptable naturalness (Hearne et al., 2008; Langevin et al., 2006; O'Brian et al., 2003; Venkatagiri, 2005).

Regulated Breathing: This technique is based on habit reversal, an intervention used for nervous habits and tics (Freeman & Friman, 2004; Woods et al., 2000). Regulated breathing strives to modify the breathing pattern of the individuals who stutter using components such as relaxation, awareness, competing response, motivation, and generalization training (Freeman & Friman, 2004; Woods et al., 2000).

Syllable-Timed Speech: This treatment involves saying each syllable in time to a rhythmic beat (Andrews et al., 2016; Law et al., 2018). For example, the patient paces their speech with the beat of a metronome (Law et al., 2018). Syllable-timed speech is thought to reduce stuttering by reducing stress contrasts across syllables (Law et al., 2018; Trajkovski et al., 2009) and controlling speech rate.

Time-out: This operant-conditioning technique involves a deliberate pause after a moment of stuttering (Hewat et al., 2006). The procedure, which can be administered by a clinician or self-administered by the client, is effective in reducing disfluency for adults, school-age and pre-school age children (Hewat et al., 2006; R. Martin & Berndt, 1970; R. R. Martin et al., 1972; Onslow et al., 1997).

Adjunct Techniques

Cognitive Behavioural Therapy: CBT programs are implemented along with speech restructuring programs,

such as the Comprehensive Stuttering program and the Camperdown Program, for individuals experiencing debilitating levels of social anxiety related to stuttering (R. Menzies et al., 2019; R. G. Menzies et al., 2008; R. G. Menzies et al., 2019). CBT entails challenging negative thoughts through means, such as individual counseling, group problem-solving discussions, and systematic desensitization to stuttering (Gunn et al., 2019; R. Menzies et al., 2019). Commonly implemented CBT program for individuals who stutter is an individualized, online program called iGlebe (Gunn et al., 2019; Helgadóttir et al., 2014; R. Menzies et al., 2016; R. G. Menzies et al., 2019). This program includes seven modules that strive to reduce social anxiety among individuals who stutter (Gunn et al., 2019; R. G. Menzies et al., 2019).

Self-Disclosure: Self-disclosure is fundamentally self-advertising, such that marginalized or stigmatized people share personal information about them with others (McGill et al., 2018). The purpose of self-disclosure is two-fold: (1) to reduce the sensitivity to and/or promote acceptance of stuttering and (2) to reduce any negative listener biases (Healey et al., 2007; Lincoln & Bricker-Katz, 2008).

Self-Modelling: Self-modeling is a technique in which a target behaviour or maladaptive situation is recorded and reviewed by client and clinician to learn new skills or adjust to challenging environments (Cream et al., 2010; Cream et al., 2009; Harasym et al., 2015; Webber et al., 2004). This technique not only provides information about how to produce the target behaviour, but also enhances self-efficacy (Cream et al., 2010; Cream et al., 2009).

Support Groups: In support or self-help groups, individuals who stutter gather to discuss similar experiences, struggles, avoidance behaviours and types of disfluencies (Boyle, 2013; Liddle et al., 2011; Yaruss et al., 2002). Support groups offer a multitude of benefits for individuals who stutter including: (1) increased opportunities for social interactions, (2) increased affiliation with a community comprised of people who stutter, (3) cognitive restructuring and changing beliefs about self-identity, (4) increased self-disclosure of stuttering to other people, and (5) improvements in self-acceptance, confidence, and self-image (Boyle, 2013; Trichon & Tetnowski, 2011; Yaruss et al., 2002).

Technology-Driven Tools in Stuttering Interventions

Over the past few years, there has been considerable technological advancement in the field of speech therapy. Prominent technological tools used in the stuttering interventions, specifically, include AAF devices (e.g., SpeechEasy), metronomes, and EMG biofeedback. Other technological tools that are being increasingly used in stuttering interventions include virtual reality, telepractice and mobile applications.

Virtual Reality (VR) includes computer-generated simulations in which users are immersed in the simulated version of real-world situations virtually. VR immersion interface includes a visual interface (headset) that can be combined with other interfaces (e.g., joystick, speakers) to provide immersive and dynamic experiences (Fuchs, 2017). This technology has been effectively used to support complimentary treatment approaches such as the adaptation effect and desensitization therapy in a controlled, safe and confidential (Brundage et al., 2016; Moise-Richard et al., 2021).

Other than VR, speech-language pathologists have been increasingly reliant on telepractice since the COVID-19 pandemic (Kollia & Tsiamtziouris, 2021). Telepractice allows for the provision of professional healthcare over the internet. These services can be synchronous (i.e., video or audio conferencing), asynchronous (i.e., e-mail) or hybrid (i.e., a combination of synchronous and asynchronous; Haynes & Langevin, 2010). Telepractice also includes benefits such as cost and time effectiveness, and increased accessibility to healthcare (e.g., decreased travel time, easy access from remote locations and during circumstances such as the COVID-19 pandemic; Brignell et al., 2021; Kollia & Tsiamtziouris, 2021; McGill et al., 2019). Telepractice has been successfully

incorporated in stuttering treatment programs, such as the Lidcombe and Camperdown programs.

To provide supplemental support for stuttering management, mobile applications have been developed. These applications can be accessed using smartphones and/or tablets. Commonly, these applications offer practice exercises that incorporate fluency induction and/or stuttering modification techniques, along with real-time feedback based on artificial intelligent evaluation of users' performance (Prasanna & Perera, 2019). SLPs have used mobile applications to support the clients' prescribed plan to boost fluency as well (Yuen et al., 2021). The use of technologies, such as those described above, can streamline treatment practices, enhance speech fluency and improve communication attitudes of people with stuttering (Almuhi, 2021).

Given the positive impact technological advancements can have on conventional treatments, it is worthwhile to investigate the potential for artificial intelligence (AI) in stuttering interventions. Investigation into the potential for AI-based technologies, such as social robots, can present novel and practical ways to assist SLPs and their clients with stuttering. Social robots are advanced AI-based technologies that "engage people in an interpersonal manner, communicating and coordinating their behaviour with humans through verbal, nonverbal, and/or affective modalities" (Breazeal et al., 2016). Social robots have been used in multiple healthcare areas, including supporting the wellbeing and functioning of persons with dementia, Autism Spectrum Disorder (ASD), diabetes and cancer (Casas et al, 2020). In the area of communication disorder, social robots have been employed to boost engagement in therapy sessions (Charron et al., 2019; Shimaya et al., 2016), enhance articulation, verbal participation and spontaneous conversations (Silvera-Tawil et. al., 2018), and phonological, morphosyntactical and semantic communication (Robles-Bykbaev et al., 2016).

Despite such promising results and constant innovation in stuttering interventions, investigations into the potential utility of social robots are nonexistent. To initiate exploration into potential of social robots for stuttering interventions, it is critical to understand the different stuttering treatment approaches that have been used or are being used to support individuals with this disorder. This comprehensive survey and review serves as a first step in informing researchers both in the fields of HRI and stuttering about the stuttering interventions that have been reported in the past two decades. With the knowledge of these treatment approaches, researchers in both fields can map the incorporation of social robots in conventional interventions.

Conclusion

This article presents a comprehensive survey and review of stuttering interventions that have been reported between 2000 and 2020. As demonstrated in our comprehensive survey of stuttering interventions (see Table 1), there is a wide range of evidence-based behavioural intervention programs (11), fluency induction techniques (9) and adjunct treatment approaches (7) that support individuals who stutter. The most commonly reported treatment program is the Lidcombe Program and the most commonly reported fluency induction technique is altered auditory feedback (AAF). To the best of our knowledge, this constitutes a timely summary of current practice for stuttering interventions that provides a starting point for collaborative projects involving clinicians, clients, researchers and social roboticists.

While this article is quite wide-ranging and elaborate, there are limitations to this comprehensive survey. First, there were restrictions regarding the number of papers that could be accessed on two databases, ASHA and Google Scholar. ASHA restricted the number to 500 titles and Google Scholar restricted the number to 1000 titles per query. The second restriction of this comprehensive survey was the unfortunate unavailability of full-text for 113 extracted papers due to COVID-19 restrictions implemented by a number of libraries. The third limitation of this comprehensive survey was the limited the number of databases used for extracting papers. As the scope of the stuttering research is substantial, we limited ourselves to three databases.

Despite these limitations, the results from the comprehensive survey and review stuttering can will be adequately used to explore the potential applications of social robots to aid people with stuttering. Based on the knowledge gathered from this comprehensive survey and review, we plan to investigate the feasibility of social

robots in stuttering therapy by conducting pilot studies in collaboration with SLPs. We further plan to conduct surveys to understand the perceptions of SLPs towards incorporation of social robots in specific stuttering interventions.

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Declaration of Competing Interest

The authors report no declarations of interest.

Ethics Approval Statement

The ethics approval from the Institutional Review board was not required, as the authors did not conduct research directly with human subjects.

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