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Investigating SATPAC Intervention Intensity for remediation of misarticulated /s/ and /z/

By Matthew Swagerty

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Science in the Department of Communication Sciences and Disorders

Idaho State University

August 2022

To the Graduate Faculty:

The members of the committee appointed to examine the thesis of Matthew Swagerty find it satisfactory and recommend that it be accepted.

Alycia Cummings, Major Advisor

Kristina Blaiser, Committee Member

Deanna Dye, Graduate Faculty Representative

Human Subjects Committee Approval

May 4, 2020

Alycia Cummings
College of Rehabilitation Comm Sciences
1311 E. Central Drive
Meridian, ID 83642

RE: Study Number IRB-FY2020-258 : Comparing the effectiveness of in-person and telepractice speech intervention programs

Dear Dr. Cummings:

Thank you for your responses to a previous review of the study listed above. These responses are eligible for expedited review under OHRP (DHHS) and FDA guidelines. This is to confirm that I have approved your application.

Notify the HSC of any adverse events. Serious, unexpected adverse events must be reported in writing within 10 business days.

You may conduct your study as described in your application effective immediately. The study is subject to renewal on or before May 4, 2021, unless closed before that date.

Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Tom Bailey (208-282-2179; email humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP Human
Subjects Chair

April 5, 2021

Alycia Cummings
College of Rehabilitation Comm Sciences

1311 E. Central Drive
Meridian, ID 83642

RE: Study number IRB-FY2020-258: Comparing the effectiveness of in-person and telepractice speech intervention programs

Dear Dr. Cummings:

You are granted permission to continue your study as described effective immediately. This study is not subject to renewal under current DHHS (OHRP) regulations.

As with the initial approval, changes to the study must be promptly reported and approved. Contact Tom Bailey (208-282-2179, humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

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ABSTRACT

Purpose: This study examines how dose frequency affects motor-based articulation remediation and generalization in school-aged children with speech sound disorders (SSD).
Background: Children with SSD are treated by nearly 90% of school based Speech Language Pathologists (SLPs). SLPs are required by the Individuals with Disabilities Education Act (IDEA) to provide intervention in an environment that is the least restrictive to the student. Currently, little evidence is provided for SLPs making service delivery decisions for children on their caseload, leading to a reduction of individualization for various severities and impairments. SATPAC is a motor-based approach SSD intervention which implements nonwords to change an inaccurate motor plan producing errored sounds. This approach utilizes the principles of motor learning to create an optimal environment for children to relearn an accurate motor plan.
Methods: Using a multiple-baseline, single-subjects experimental design, three English-speaking children with SSD (6;1-8;11) were split into two dose frequency conditions (2 children in one condition, 1 child in the second condition) targeting dentalized /s/ error patterns. Children received between 16 and 18 hours of treatment provided twice per week (2x/week) for 30 minutes per session or three times per week (3x/week) for 20 minutes per session.
Results: All three participants demonstrated large effect sizes with a Tau-U value greater than 0.8 with statistically significant ($p<0.01$) improvement in their /s/ production accuracy on the 60-word /s/ probe between initial assessment and final assessment.
Conclusion: Intervention provided twice a week for 30 minutes and three times a week for 20 minutes resulted in similar intervention outcomes suggesting that both intervention session schedules can elicit change in children’s speech production. The higher dosage achieved with the participant receiving more frequent but shorter sessions suggests that shorter sessions may be more effective.

Keywords: Dentalized, Intervention intensity, Lisp, Speech Sound Disorders

Introduction

In 2012, an International Expert Panel on Multilingual Children's Speech provided a comprehensive definition of specific impairments or difficulties that children with speech sound disorders (SSD) may encounter. They determined that children with SSDs can have any combination of difficulties with perception, articulation/motor production, and/or phonological representation of speech segments (consonants and vowels), phonotactics (syllable and word shapes), and prosody (lexical and grammatical tones, rhythm, stress, and intonation) that may impact speech intelligibility and acceptability. Nearly 90% of all school basedSpeech Language Pathologists (SLPs) treat students with SSDs and children with SSDs make up 39% of a typical caseload of 48 students, representing the second most treated disorder in school settings (ASHA, 2020). SSDs are broken down into two primary categories: motor-based (articulation) SSDs and phonological SSDs.

The differences between these two types of SSDs are subtle but require different approaches to remediation. Children with phonological SSDs demonstrate errors in understanding the phonological rules of a language because their underlying representation of a phoneme is inaccurate or imprecise. These errors can often present as consistent patterns of errors, or phonological processes (e.g., consistently substituting velar sounds like /k/ and /g/ for alveolar sounds like /t/ and /d/). Children with a phonological SSD can have multiple phonological processes present in their speech. A phonological SSD treatment will target the pattern of errors instead of the production of a single sound. Phonological treatment will also target the child's overall understanding and awareness of the rules of the sound system of the language.

Children with motor-based SSDs demonstrate errors with movement of the articulators to produce accurate speech sounds. Motor-based SSDs represent an impairment in either the motor planning, programming, or the execution of the speech sound. For example, Childhood Apraxia of Speech (CAS) is a disorder in the planning and programming of the speech sounds necessary for a word, but this disorder is relatively uncommon (0.1%–0.2%; Shriberg et al., 1997). The most common motorbased SSD is an impairment in executing the motor plan, which often presents as errors in individual speech sounds (e.g., consistent /s/ distortions). Treatment for motor-based SSDs consists of treatment focusing own accurate production of producing a specific speech sound. To encourage accurate production, SLPs need teach a new motor plan to replace the existing errored plan. To teach a motor plan, the principles of motor learning could be implemented to provide a greater opportunity for the child to learn the correct production.

Principles of Motor Learning

The principles of motor learning (PML) are a series of guidelines that breakdown motor learning into two important areas: practice and feedback. Both practice and feedback are broken-down into further conditions that each represents a continuum along which the SLP can adjust intervention for the greatest opportunity for motor learning (Maas et al., 2008). Practice conditions include practice amount, practice distribution, practice variability, practice schedule, attentional focus, and target complexity. *Practice amount* refers to the total number of trials in a practice session, which could also be referred to as dose. *Practice distribution* refers to massed (practice targets for a short period of time) or distributed (practice for a specific target is spread out over a longer period of time). *Practice variability* refers to constant practice (practice one target in one context) or variable (practice multiple targets in more than one context). *Practice schedule* refers to blocked (one target is treated then another target is treated) or random (multiple targets are treated at the same time, switching at random between the targets).

Feedback conditions include feedback type, feedback frequency, and feedback timing. *Feedback type* refers to whether the SLP is providing feedback on how the child moved their mouth to produce the sound (knowledge of performance) or what the result of the movement was (i.e., the sound that come out; knowledge of results). *Feedback frequency* refers to how often the SLP provides feedback, ranging from every production to once every few productions. *Feedback timing* refers to the time between the child's production and the feedback from the SLP, this ranges from immediately after the production to multiple seconds after the production. Each of these conditions of practice and feedback can be adjusted by the SLP to provide individualized treatment leading to greater motor learning.

Guadagnoli and Lee (2004) developed the challenge point framework to support SLPs in providing the greatest opportunity for motor-based learning. The challenge point framework creates a point where the functional difficulty (the difficulty of the task at the child's current skill level) is met with appropriate amount and type of feedback where the child can learn. This framework draws a significant resemblance to Vygotsky's theory of zone of proximal development (Vygotsky, 1978). The zone of proximal development refers activities with a difficulty level that the learner can do with guidance or assistance from the teacher (Vygotsky, 1978). The SLP's goal for therapy is to consistently adjust treatment to remain at the challenge point. As the child's skill level increases, the functional difficulty decreases if the task remains the same. Therefore, the SLP should increase the difficulty of the task or decrease the level of feedback as the child's skill level increases. While the SLP is adjusting the difficulty of the task, they should keep in mind the practice and feedback conditions of the intervention to ensure that the ideal conditions for motor learning are present.

That being said, Matthews, Morrison, and Rvachew (2021) observed that SLP expectations for accuracy when utilizing the challenge point framework did not provide the highest probability of motor learning. They determined that SLPs often expect accuracy to range from 60-80% for effective treatment, but motor learning can occur at accuracy levels as low as 50%. Motor-based treatment following the principles of motor learning are the most frequently used treatment approach for dental lisps or misarticulated /s/.

Misarticulated /s/

Dentalization of the /s/ and /z/ sounds (i.e., dental lisps) is the most common production error in the English language (Shriberg, 2019). Dental misarticulations are often the result of an inaccurate motor plan or execution that results in improper placement of the tongue. This type of error is often categorized as a mild speech sound disorder due to the limited impact on overall speech intelligibility, but like many children with more severe SSDs, children with dentalized /s/ and /z/ productions experience social-emotional challenges of life with an SSD (Hitchcock et al., 2015). Often the primary method for correcting this type of misarticulation is the traditional method developed by Van Riper (1972). The traditional treatment approach starts by teaching correct articulator placement, followed by producing the sound in isolation and moving all the way through the linguistic complexity hierarchy until the child can produce the sound in connected speech. This method of remediation has received mixed results with treating /s/ and /z/ misarticulation and has demonstrated difficulty with maintenance and generalization (Ruscello 1995). Inconsistency in labeling of misarticulated /s/ and /z/ made finding additional treatment approaches difficult.

Sacks and Shine (2004) developed the Systematic Articulation Training Program Accessing Computers (SATPAC) as a method for remediating misarticulated /s/, /z/, and /ɹ/. SATPAC utilizes practice and feedback conditions from the principles of motor learning to facilitate change in misarticulated sounds. A series of nonsense words are used to create a consistent motor pattern for the targeted sound as well as break habitual patterns of misarticulation that have been practiced with real words. The SATPAC approach follows the principles of motor learning to alter the motor plan beginning with a single sound, then a nonsense word. After the client has success with the nonsense word, a variety of other nonsense words are practiced increasing the randomness. After the nonsense words are practiced, nonsense sentences and generalization phrases and sentences are practiced. SATPAC places heavy emphasis on ensuring the child can produce the targeted sound at a normal speaking rate.

Sacks, Flipsen, and Neils-Strunjas (2013) studied the efficacy of SATPAC on 18 school-aged children (6;9 to 11;10 years) with dentalized for /s/ and /z/. Each of the two quasi-randomized groups acted as their own baselines and demonstrated statistically significant ($p<.001$ and $p<.001$ respectively) increases in Percent Consonants Correct

(PCC) after receiving treatment in 10-minute sessions once per week for 15 weeks. At the two-year follow-up assessment, all students demonstrated maintenance of significant gains from baseline. The increase in accuracy demonstrated by the clients was statistically significant (p =.003).

Flipsen and Sacks (2015) used a single case study design to determine the efficacy of the SATPAC approach on remediation of residual /ɹ/ errors. SATPAC uses a similar procedure to remediate /ɹ/ as it does for /s/, save for the root words and placement instructions. In this study the 8-year-old participant was seen for seven 30-minute sessions administered over 7 weeks and two follow-up sessions to ensure maintenance. This study did not include any pretreatment assessment other than an informal screening which concluded that, “he was not producing /ɹ/ correctly in any context” (Flipsen & Sacks, 2015, p. 67). After treatment, the child was reported by three independent SLPs to have increased /ɹ/ accuracy to 90%, 88% and 87% respectively. Without pretreatment assessment it is difficult to ascertain the efficacy of SATPAC in remediating /ɹ/, but anecdotally, some promise is demonstrated its usefulness. Overall, these studies have demonstrated of the efficacy of the SATPAC program, but more research is necessary.

One of the key components of motor-based treatment is the intensity of the practice, with more trials in a session (higher dosage) usually eliciting greater change than fewer trials (Maas et al., 2008). SATPAC is designed to elicit many trials, however it has not been reported exactly how many trials children might need to experience in order to experience significant change in their sound system. While Sacks and colleagues (2013) provided intervention in 10-minute sessions once per week for 15 weeks, they provided no information about dose within each session making it impossible to calculate cumulative intervention intensity. Flipsen and Sacks (2015) provided intervention in 30-minute sessions with 300-400 trials in each session, but they provided no information about dose frequency, again making it impossible to determine intervention intensity. The SATPAC approach was designed to be implemented by a school based SLP who are frequently pressed to reduce treatment time due to caseload/workload constraints.

Current Practices

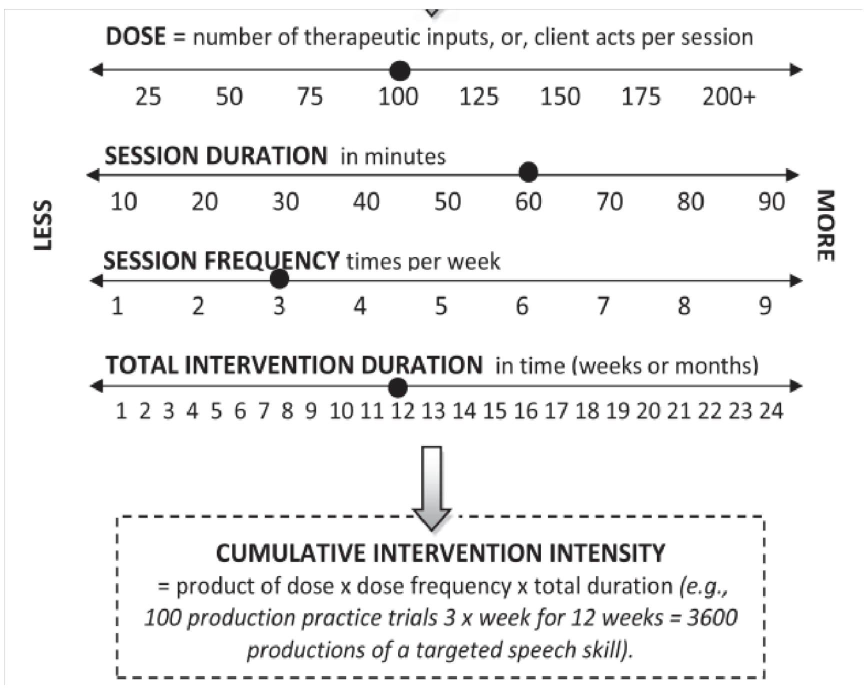
School based SLPs are governed by the Individuals with Disabilities Education Act (IDEA, 2004), which ensures that students with disabilities receive free, appropriate education. IDEA says that special education should be provided in the Least Restrictive Environment (LRE) which ensures that “that children with disabilities are educated with children who do not have disabilities, to the maximum extent appropriate.” The least restrictive environment for a student means the SLPs should plan intervention that will demonstrate improvement without keeping the student isolated from their peers in the general education classroom longer than necessary. To best meet the mandates of IDEA, school based SLPs need to consider their clinical service delivery model to ensure that they are providing the most efficient, and effective, services to their students. For example, intervention intensity should be considered to ensure that students are being scheduled with their ideal outcomes in mind.

Intervention Intensity

Intervention intensity is the combination of dose frequency, dose form, total intervention duration, dose, and cumulative intervention intensity (Warren et al. 2007).

Dose frequency represents the number of intervention sessions that the student will receive each week. *Dose form* represents the method by which the “active ingredient,” is administered; essentially, it is the intervention method, such as SATPAC. *Total intervention duration* represents the number of weeks or months the student will be receiving intervention. Overall, dose represents the total number of teaching episodes

Figure 1. The components of intervention intensity and how an SLP might use them to determine cumulative intensity for each of their students (Baker, 2012).



within a session. *Cumulative intervention intensity* is the dose x dose frequency x total intervention time which results in the total dose over the course of the intervention (e.g., 100 trials x 3 sessions/week x 10 weeks = 3000 trials) shown in Figure 1.

School based SLPs treating students with SSDs make decisions about intervention intensity based on schedule or severity of the disorder (Brandel & Loeb, 2011). However, even though SLPs use severity to determine intervention intensity, the variation in scheduling clients with high and low severity is minimal. SLPs reported the severity of a student's disorder as a primary factor in service delivery decisions, but the intervention intensity provided for children with higher severity SSDs was very similar to the intensity provided for children with lower severity SSDs. (Brandel & Loeb, 2011). In another survey, Sugden et al. (2018) found that a majority of Australian SLPs did not make decisions about intervention intensity, they simply allocated the 20-30 minutes of intervention twice per week for each of their students. The lack of variation for students receiving intervention for SSDs demonstrates the lack of information and evidence for the appropriate intervention intensity.

Table 1 provides a summary of the current literature regarding intervention intensity. It includes much of the research that SLPs use in making service delivery decisions for their caseload. Each study includes a summary of that article's contribution to the body of literature on intervention intensity.

Table 1. Current intervention intensity research for children with SSD.

Authors	Type (Survey, intervention Study, Review, or Meta-analysis)	Description and Summary of Outcomes
Allen (2013)	Intervention Study	A Randomized Controlled Trial (RCT) designed to determine whether the Multiple Oppositions approach applied three times per week (3x/week) had better outcomes when compared to one time per week (1x/week). Allen determined that over an 8-week period, preschoolers receiving intervention 3x/week outperformed peers receiving intervention 1x/week. Allen also determined that over 24

		sessions, preschoolers receiving intervention 3x/week outperformed peers receiving intervention 1x/week. Ultimately, this study provides support for the theory that dose frequency has a significant impact on outcomes.
Nissen, Peris & Tanner (2017)	Intervention Study	This study analyzed the progress of a single 8year-old child during a two-day intensive boot camp (5.5 hours each day for 2 days) using the traditional treatment approach to determine the efficacy of a high intensity intervention program. Nissen et al. found that intervention for interdental /s/ produced statistically significant outcomes for the child with maintenance one-week posttreatment.
Cummings, Hallgrimson & Robinson (2019)	Intervention Study	This study examined cumulative intervention intensity for the traditional treatment approach to determine if more intervention sessions (19) would lead to greater outcomes than fewer intervention sessions (11) for children ages 3;6 to 6;10 with SSD. Cummings et al. confirmed the hypothesis that a greater number of intervention sessions led to greater outcomes for children with SSDs. The children with a greater number of intervention sessions achieved six times the improvement in sound accuracy than the children with fewer sessions.
Namasivayam, Pukonen, Goshulak, Granata, Le, & Kroll (2019)	Intervention Study	This study looked at the impact of intervention intensity on Motor Speech Treatment Protocol (MSTP) for treating preschool children (average age of 3;9) with SSDs that demonstrated signs and symptoms of motor speech impairment. Namasivayam et al. determined that over 10 weeks, there was not a significant difference between outcomes for children in the high frequency group (2x/week) and the low frequency group (1x/week). The findings of this study contradict the findings from Cummings et al. (2019), which could be the result of differences between phonological and motor treatment.

Cummings, Giesbrecht, & Hallgrimson (2021)	Intervention Study	This study sought to determine if using the traditional treatment approach with a higher intensity (4x/week) would provide greater improvement over a lower intervention intensity (2x/week) among children aged 4;0 to 5;6 with SSDs. Cummings et al. found that both low and high intensity intervention provided similar generalization for phonological treatment. This study provides support for the blocked treatment schedule in which children receive intervention at a high intensity for a short amount of time and still achieve similar outcomes to treatment spread out over a longer period of time.
Byers, BellonHarn, Allen, Saar, Manchaiah & Rodrigo (2021)	Intervention Study	This study looked at whether students (5;2 to 9;11) receiving motor-based individual intervention for a shorter amount of time would have similar outcomes to children receiving group intervention for a longer amount of time. Byers et al. found significant improvement in children's speech production abilities when motor-based traditional intervention was provided in 5-minute individual sessions three times per week as compared to 30minute group sessions occurring twice a week. This information provides some guidance for school based SLPs treating students with motorbased SSDs but comparing overall intervention intensity is difficult when analyzing group sessions and individual sessions simultaneously. This study presents evidence supporting the efficacy of alternative service delivery models but does not provide SLPs with guidance on the ideal intensity.
Brandel & Loeb (2011)	Survey	Brandel and Loeb sought to determine the reasoning by which school based SLPs made decisions about the intensity and service delivery models for their students. They found that even though SLPs stated that they made intensity decisions to provide individualized intervention for their students, the variation between disabilities and severities was negligible.

Hegarty, Titterington, McLeod & Taggart (2018)	Survey	This survey sought to understand the clinical management of phonological SSD by Speech Language Therapists (SLTs) in the UK. Hegarty et al. determined that there was a large difference between the reported ideal intensity and the actual intensity provided. Most reported 9-12 sessions between 21 and 30 minutes, but when asked about ideal intensity they reported 21-30 sessions of 21-30 minutes.
Hegarty, Titterington & Taggart (2021)	Survey	This study expands on the previous survey conducted by Hegarty et al. (2018). Hegarty et al. (2021) found that SLTs reported large caseloads and limited resources as barriers to provide intervention with the intensity reported in the literature. SLTs also reported that their work setting had a large impact on their intensity decisions, comparing the increased flexibility of a specialist or an SLT manager with that of a community based SLT (comparable to a private practice SLP). They reported that community based SLTs had limited flexibility to offer a higher intervention intensity. Finally, SLTs reported that expectations for parent compliance were a significant barrier to increasing intervention intensity. Parent compliance was introduced as a barrier due to uncertainty about family/caregiver agreement to participate in the dose frequency often supported in the literature (2-3 sessions per week).
Baker & McLeod (2011)	Narrative Review	This review looked at a variety of topics across multiple treatment approaches that are commonly used to treat children with SSDs. Baker and McLeod determined that in many of the studies, intervention occurred in a university clinic with sessions ranging from 30-60 minutes. They also found that out of 134 studies analyzed, only 37 of them matched the intensity trends reported by SLPs of twice a week for 21-30 minutes. They

		reported uncertainty about the optimal intervention intensity for SSD treatment.

Williams (2012)	Systematic review	This study looks at a series of intervention studies for the Multiple Oppositions approach to determine the appropriate intensity. Williams determined that the appropriate dose for Multiple Oppositions includes 70 trials in a session with a minimum of 50 trials.
Zeng, Law, and Lindsey (2012)	Systematic Review	This study analyzed multiple articles that included intervention intensity to determine if there was an impact on outcomes or effect size. They also looked at the impact on dose for multiple intervention types including intervention for phonological, semantic, and syntactic impairments. Zeng et al. found that there was no emerging consensus on the most effective intervention intensity. The heterogeneity of the approaches examined in this study made finding an optimal intensity difficult. Future research might have a higher likelihood of determining appropriate intensity by focusing on fewer approaches.

Kaipa & Peterson (2016)	Systematic Review	This review looked to determine if any studies provided optimal intensity for a variety of disorders including SSD, dysarthria, and Apraxia of Speech and if there was any consistency among them. Kaipa and Peterson determined that in general, higher intensity was more beneficial for the client. They also introduced an important point about intervention intensity. That is, while investigating intensity, SLPs and researchers should use patient reported outcome measures (PROMs) to ensure that the chosen intensity is perceived to be beneficial by the client. Future researchers should include PROMs as well as maintenance and/or generalization information. One potential limitation for this study's application to intervention for SSDs is that only one intervention study on SSDs (Allen, 2013) was included in this review.
Sugden, Baker, Munro, Williams, & Trivette (2018)	Meta-analysis	This study looked to determine what evidence exists about the optimal intensity for phonologybased SSDs, as well as a survey to determine what Australian Speech Language Therapists (SLTs) found to be most effective for treating students with phonology-based SSDs. Sugden et al. determined that 2-3 pull-out group sessions/week for 20-30 minutes remains the
		default intensity for every student. While this study provides evidence about the current practice of SLPs, optimal intervention intensity remains unknown.

Multiple researchers have approached intervention intensity from a variety of different angles. Some intervention studies altered dose frequency (Allen, 2013, Cummings et al., 2021) or cumulative intervention intensity (Cummings et al., 2019, Namasivayam et al., 2019, Nissen et al., 2017). Each of these studies provides a piece of the picture about optimal intervention intensity and supports the idea that SLPs should start to change their service delivery practices from BAU (two, 30-minute sessions each week). Some studies surveyed current practices of SLPs and SLTs to determine current practices (Brandel and Loeb, 2011, Hegarty et al., 2018, Hegarty et al., 2021). These studies found that most SLPs provide intervention at a lower intensity than they believe to be ideal, but barriers to increased intervention such as family compliance and caseload constraints limited their ability to increased intensity.

Multiple literature reviews were conducted to determine if a pattern could be observed to determine the ideal intervention intensity (Baker & McLeod 2011, Williams 2012, Zeng et al., 2012, Kaipa et al., 2016, Sugden et al., 2018). These studies had a variety of findings, some of which confirmed reported intensity from previous surveys, while others determined that, in general, higher intensity was more effective for children with SSDs. One study failed to determine an optimal intensity across a variety of approaches to intervention. The heterogeneity demonstrated by each of the reviews failed to provide any consensus on an optimal intervention intensity for treating children with SSDs.

Telepractice

Telepractice, or providing intervention through digital medium, has significantly increased due to the Covid-19 pandemic. In 2005 the American Speech and Hearing Association (ASHA) approved the use of telepractice to provide intervention to children and adults with speech and language disorders (ASHA, 2005). In 2011, GrogenJohnsen et al. (2011) determined that providing intervention for SSDs resulted in similar significant gains as side-by-side intervention. A high level (over 90%) of agreement was obtained between face-to-face clinicians and clinicians assessing speech accuracy across three domains including single-word articulation, speech intelligibility, and oromotor function (Theodoros, 2011). The approval of telepractice by ASHA, paired with multiple studies supporting the efficacy of telepractice demonstrate that telepractice is effective for treatment of SSDs in a variety of settings.

In a research setting, parent compliance with increased intensity is a concern for SLPs due to the increased time commitment of greater dose frequency (Hegarty, 2018). For school based SLPs the barrier to increased intensity falls increasingly on caseload size (Sugden et al. 2018), and teacher compliance (Roepke et al. 2019). Roepke and colleagues reported SLPs receiving pushback from teachers when increasing intervention intensity. Teachers were frustrated with an increase of disruptions and more frequent removal of the students from the classroom. Providing intervention digitally eliminates travel time which reduces one of the barriers to providing intervention with an appropriate intensity for researchers. For school based SLPs, telepractice is an effective tool for reaching rural school districts that have a difficult time providing services for children with SSDs (Grogen-Johnsen et al. 2011). The convenience of telepractice creates an opportunity for students to have access intervention that may have been inaccessible previously (Theodoros, 2011). While telepractice is an effective tool for providing intervention remotely, it is not effective for all students and families.

Telepractice has multiple barriers to effective intervention, the first and most significant is the requirement for families to have reliable internet and computer access. Access to technology is growing among low socioeconomic populations, but it is far from universal. Another significant barrier to telepractice is providing intervention to students with behavioral challenges. This barrier is relatively unique to younger children and adolescents and can often be remedied with increased parent involvement throughout sessions. While telepractice is not right for every student, the benefits of providing intervention for SSDs over telepractice are evident and should be considered a viable option. Any SLP providing intervention for a motor-based SSD should consider telepractice due to the increased ability to provide short, frequent sessions, while also reducing the impact of previously recognized barriers to increased intensity.

Summary

SSDs are one of the most common communication disorders treated by SLPs, and among those, misarticulated /s/ and /z/ represent a large portion of those errors. The traditional treatment method for remediation has received mixed results, with primary difficulties in generalization and maintenance. SATPAC is a motor-based approach to remediating /s/, /z/, and /ɹ/ errors employing the principles of motor learning to adjust the conditions of intervention to increase probability of learning correct speech motor patterns. Using nonwords, this approach reduces reliance on inaccurate habitual motor patterns that produce misarticulations. The evidence for this program is emerging, though only two peer-reviewed sources support its efficacy. Additionally, possible conflicts of interest are present due to the lack of independent research on the efficacy of SATPAC. Recent research has provided support for variation from business-as-usual scheduling for SSD intervention (Byers et al., 2021, Roepke et al. 2019). Further research is necessary to provide support for SLPs when making intensity and service delivery decisions to meet IDEA requirements.

The present study aims to determine the ideal intervention intensity for providing motor-based intervention to children with speech sound disorders (SSDs). While most

SLPs continue to provide intervention in two 20- to 30-minute sessions each week (Sugden et. al, 2018), researchers have determined that intervention provided at a higher intensity (Allen, 2013, Byers et al., 2021, Cummings et al., 2019, Cummings et al., 2021, Kaipa et al., 2016, Roepke et al., 2019) can elicit equal or greater outcomes. Each of these studies modifies one or more elements of cumulative intervention intensity, but none maintain the weekly intensity. This study evaluates the impact of intervention intensity while maintaining one hour of treatment each week for each participant.

In this study, the weekly time received by each participant will remain consistent (1 hour). The consistent weekly intensity with variation in dose frequency is expected to result in similar total intervention intensity. It is hypothesized that providing treatment in three 20-minute sessions each week will not generate significantly different increases in production accuracy of /s/ and /z/ when compared to two 30-minute sessions each week. The findings of this research will provide information to SLPs that will assist in clinical service delivery decision making. If three 20-minute sessions can elicit similar outcomes as that of two 30-minute sessions, it could provide more scheduling flexibility for school based SLPs, which would help manage their caseloads.

METHODS

Experimental design. A multiple baseline, single-subjects experimental design, in which every child served as his/her own control, was used in this telepractice speech intervention program (McReynolds & Kearns, 1983). This design has been used effectively in many different types of intervention studies involving children with SSD

(Cummings et al., 2019, 2020; Cummings & Barlow, 2011). Following procedures for this design, the children with SSD were randomly assigned to one of two intervention conditions: 1) intervention occurring two times per week (2x/week) for 30 minutes or 2) intervention occurring three times per week (3x/week) for 20 minutes. Thus, every child was provided with one hour of intervention each week. Every child was evaluated in a baseline period in which no intervention was provided, followed by up to 20 hours of speech intervention. This consisted of either 40, 30-minute sessions (2x/week) or 60, 20-minute sessions (3x/week) resulting in 20 weeks of treatment for all children.

Participants. Three English-speaking male children (ages 7;5, 7;8, and 8;11) with SSD were recruited to participate in this speech intervention program. The children were randomly assigned to one of two intervention dose frequency conditions: 2x/week (Child 1-2) and 3x/week (Child 3). Within each intervention condition, child 1 received 18 hours of treatment, child 2 and 3 received 17 hours of treatment. A parent or guardian of each child signed informed consent in accordance with the Idaho State University Human Research Protection Programs.

Each child met all of the following study criteria: (a) residence in a monolingual English-speaking household; (b) typical speech structures and functions as measured by an oral-peripheral mechanism exam administered via Zoom in the telepractice environment; (c) percentile score at or below 10 on the *Goldman-Fristoe Test of Articulation, 3rd edition* (GFTA-3; Goldman & Fristoe, 2015); (d) less than 30% accuracy on the initial /s/ word probe as judged by the SLP; (e) parent report of normal hearing as measured by a hearing test in the past 12 months.

Pre- and Post-Intervention Baseline Speech Probes. Two speech probes were administered across four sessions prior to starting intervention: 1) the S-Probe (in appendix) in which /s/ was elicited in 60 untreated words – this was administered three times in three different sessions and 2) a Polysyllabic Word Probe (in appendix) in which a list of 50 untreated words were elicited including three, four, and five syllable words. In addition, participants completed the S-Probe after 5, 10, and 15 hours of participation in the intervention program, as well as post-treatment. In addition to the single-word speech probes, children's pre- and post-intervention speech production accuracy in connected speech was measured using the narrative tasks of the Test of Narrative Language – 2nd edition (TNL-2) (Gillam et al. 2017).

Speech intervention procedures. The motor based SATPAC speech intervention program (Flipsen & Sacks, 2015) was used with all children. There are four main phases of the SATPAC program: placement, establishment, practice, and generalization/transfer (Flipsen & Sacks, 2015). Each of these will be described below. Initially, all children were taught post-vocalic /s/ productions.

Placement. Treatment to remediate distorted and/or dentalized /s/ productions began by teaching correct placement using phonetic placement cues, oral-motor placement cues, and sound-shaping activities during which each child was given verbal, tactile, and physical cues to help elicit the phoneme (Secord et al., 2007). Intervention began by providing models of accurate and inaccurate productions to draw the child's attention to the correct tongue position. Specifically, the contact of the side of the tongue with the rear molars, and the position of the tongue tip high in the oral cavity at the alveolar ridge, were emphasized.

Children were initially asked to produce “ee, ee, eets”: /i/, /i/, /its/. If children demonstrated any jaw movement during the production of /s/, a bite block (created from a stack of three tongue depressors) was placed anterior to posterior between the teeth of one side of the mouth. The bite block provided stabilization to the lower jaw to provide separation between the jaw and tongue articulators. Along with the tactile cueing, a mirror/video screen were used to provide visual feedback regarding the tongue movement. The clinician provided verbal cues such as “big smile” and “pull your tongue up”.

Once the child could produce /i/, /i/, /its/, the single /i/ productions were eliminated, and children produced just /its/ for approximately 50 productions. Then the child’s SATPAC “seed word” was introduced (e.g., “eetseet”, /itsit/). These initial seed word productions were practiced in groups of 50-100 for an additional 300-400 trials prior to beginning the establishment phase.

Establishment. The SATPAC establishment phase includes seven steps involving just the production of the seed word. To progress to the next step, children must demonstrate 95% accuracy (19/20 trials). These productions are not required to be produced at a specific rate of speech, though prosodic variation is targeted. First the entire bi-syllabic seed word is spoken slowly and then just the target phoneme in the word is prolonged. The word is then produced with equal stress on both syllables, and then the stress is switched to first targeting the syllable with the target phoneme and then to the syllable not containing the target phoneme. The sixth step requires children to repeat phrases containing the seed words. The final step in the establishment phase requires the children to produce the seed word in sentences with varying linguistic stress patterns. Not all steps of the establishment phase were administered in order, as participant engagement decreased with prolonged time spent on a single step. With all participants, the first and second steps were targeted simultaneously, alternating between practicing the seed word slowly and with the target sound elongated. Like steps one and two, steps three through five were also targeted simultaneously, changing the stress at random intervals. Step six was only completed with participant 3, and step 7 was not completed by any participant.

Practice. The SATPAC practice phase includes six lists (included in appendix). The lists are designed to progressively become more difficult in their phonetic contexts and coarticulation requirements. The first five lists are consonant-vowel-consonantconsonant-vowel-consonant (CVCCVC) nonwords. The sixth list targets the VCCV nonwords in sentences with varying linguistic stress patterns.

Children were required to produce Lists 1-5 with the 80% accuracy at 140 beats per minute (BPM) using a metronome before starting the sentences of List 6. Five different sentences were targeted in List 6, with four different linguistic stress contexts. That is, the clinician would ask a question which would require the child to stress the appropriate word in each sentence. For example, one target sentence was, “I want a big “beetseet”, /bitsit/). The clinician would ask, “Do you have a big beetseet?” and the child would be expected to say, “No, I have a big beetseet”, with extra emphasis on the “I”. Once children were able to produce all these sentences without slowing down on the target phoneme/word, they moved onto the generalization/transfer phase.

Generalization/Transfer. Real words were introduced during the generalization/transfer phase through the production of phrases, short sentences, and longer sentences. Importantly, during this phase, children were taught to monitor their /s/ productions with a tally counter. Specifically, children were asked to push the tally counter when they produced /s/ correctly.

After all the phrases and sentences for /s/ were completed, intervention shifted to conversation-level speech. The tally counter continued to be used to support selfmonitoring of accurate productions. Once children were 80% accurate in conversational speech, they were dismissed from the intervention program.

To track intervention progress, at the beginning of each 60-minute segment of intervention, children were asked to produce ten untreated words containing their /s/ intervention target 14 times in pre-vocalic and post-vocalic position without a clinician model (words listed in appendix). The accuracy of these word productions was tracked as a measure of untreated word generalization occurring throughout intervention.

Intervention fidelity. All sessions were audio and video recorded so that the authors could confirm that intervention for the children occurred in a similar manner. A research assistant reviewed two sessions distributed throughout the course of intervention of each child to verify the following aspects of the study design: (1) untreated probe words were elicited at the beginning of the session as required (i.e., every 60 minutes of intervention, (2) the clinician provided immediate feedback for at least 15/20 errors during the placement, establishment, and practice phases of intervention, and (3) All reviewed sessions also included the untreated word speech probe. As such, the research assistant also rated the accuracy (i.e., correct: + or incorrect: -) of the children’s treated sound in the ten untreated words. The research assistant and the administering clinician were consistent in their ratings of the children's production accuracy of the untreated words, achieving 100% reliability in 2 sessions.

Speech Probe Transcription Reliability. To ensure transcription reliability, an estimate of inter-rater agreement will be obtained. The International Phonetic Alphabet (IPA) will be used to narrowly transcribe all speech samples using the *PHON* computer transcription and data analysis program (Rose & MacWhinney, 2014). Using PHON's blind transcriber function, 100% of each child's speech probes will be reliability-checked by the clinician and a research assistant. These speech samples will then be compared for point-by-point consonant agreement. Overall, the transcriber reliability was 100% based on 14 consonants transcribed.

Data analysis.

Intervention session untreated word probes. The ten-word probes administered every 60 minutes of intervention were used as a marker of phonological generalization occurring during intervention. The clinician judged the accuracy of the target phoneme in the ten untreated words, with accuracy also judged off-line by a second research assistant. Phonemes were only counted as correct if they were produced in a manner like that of an adult in the ambient language (i.e., prolonged sounds, segmented and distorted productions were judged to be incorrect).

Generalization of intervention phoneme. Generalization is reported for the intervention phonemes in untreated words (in all word positions). To determine generalization of the intervention phonemes, percent accuracy scores for each phoneme were calculated for each administration of the *GFTA-3* (Goldman & Fristoe, 2015), *S-Probe,* and the *Polysyllabic Word Probe.* Using *PHON* (Rose & MacWhinney, 2014) each consonant was point-by-point identified as being correct or incorrect in relation to its target phoneme. Measurable intervention phoneme generalization was defined using the criterion level of 10% or greater change (Cummings & Barlow, 2011).

To establish the relative magnitude of the intervention phoneme generalization gains, two different effect size measurements were calculated. To characterize the intervention phoneme generalization at the individual child level, the treated phoneme accuracy values from each of the pre-intervention and post-intervention speech probes were put into the online Tau-*U* Calculator (Vannest et al., 2020). A Tau-*U* effect size estimate, p-value, and 90% confidence interval were then calculated. A Tau-*U* effect size of 0.20 or less indicates a “small change”, 0.20-0.60 indicates a “moderate change”, 0.60-0.80 indicates a “large change”, and 0.80 or more indicates a “large to very large change” (Vannest & Ninci, 2015).

RESULTS

The first aim of this study was to examine the impact of dose frequency and session length on remediation of dentalized /s/. Additionally, we hypothesized that the use of the SATPAC program would result in effective remediation of these errors. Initial assessment for each participant included a variety of norm-referenced and criterion referenced assessments. The *Goldman Fristoe Test of Articulation - 3rd edition* (*GFTA-3*) was the only norm-referenced assessment used to evaluate student articulation accuracy. The researchers used the Test of Narrative Language - 2nd edition (TNL-2) to obtain a sample of connected speech from each participant. Assessment also included a polysyllabic word probe consisting of 50 words including a variety of sounds (including the target /s/) in 3-, 4-, and 5-syllable words, and the S Probe that consisted of 60 words (administered three times) containing /s/ 47 times in word initial position, and 13 times word final position. Following assessment, the mean of the three S Probes was used to calculate the initial /s/ probe score.

Throughout treatment two different probes were conducted to assess participants' change in accuracy over time. After every one hour of treatment, a short /s/ probe was administered with 10 untreated words containing 14 different instances of /s/ in syllable initial and final positions. After every five hours of treatment, the S Probe was administered. Each participant completed the 60-word S Probe a total of nine times: three times during initial assessment, one time at 5-hours, one time at 10-hours, one time at 15-hours, then three times during their final assessment.

Treatment consisted of implementation of the motor based SATPAC speech intervention program (Flipsen & Sacks, 2015). SATPAC uses the principles of motor learning to reteach the accurate motor plan for an errored sound. To increase efficiency and speed of learning a new motor plan, the SATPAC program utilizes nonwords to eliminate the possibility of a previously established motor plan. There are four main phases of the SATPAC program: placement, establishment, practice, and generalization/transfer (Flipsen & Sacks, 2015). In the placement phase, the correct placement of the target phoneme /s/ was taught using a bite block and tactile stimulation. Once the placement phase was completed, therapy progressed to the establishment phase which introduced the root nonword, eetseet (i.e., /itsit/). In the establishment phase, the root word /itsit/ was trained first at syllable level production

/its/, then with /i i its/. The full word was targeted with /itsit/ after participant accuracy reached 90%. Feedback was provided throughout the establishment phase using both knowledge of performance and knowledge of results.

Once participant accuracy on the full word reached 90%, treatment moved to the practice phase. In the practice phase, a series of 6 lists that each contained 20 nonwords were taught to develop and refine the motor plan for /s/ in increasingly complex words. During the practice phase, words were required to be produced at a speed of 140 beats per minute for a list to be considered completed. Once all 6 lists were completed, therapy progressed into the generalization and transfer phase in which real words were introduced in increasing levels of linguistic complexity from word level to conversational speech.

To measure intervention intensity, the SLP recorded the total number of teaching sessions (dose) performed in each session, as well as the number of sessions per week (dose frequency) and multiplied by the total number of weeks to determine the overall intervention intensity of the treatment.

Data analysis included determining effect size of the change in accuracy on the 60word /s/ probes using a Tau-U effect size calculator. A Tau-*U* effect size of 0.20 or less indicates a “small change”, 0.20-0.60 indicates a “moderate change”, 0.60-0.80 indicates a “large change”, and 0.80 or more indicates a “large to very large change” (Vannest & Ninci, 2015).

Participant 1

Participant 1 completed 36 sessions, for 18 hours of treatment, scheduled roughly two times per week for 30 minutes each. Due to cancellations by the Participant's family, these sessions were spread out across 28 weeks.

Intervention Intensity

Across 18 hours of treatment, Participant 1 received an average dose of 75 teaching episodes for each 30-minute session which occurred two times week. The weekly dose provided to Participant 1 was 150 teaching episodes for each hour of treatment. This allows the SLP to calculate the total intervention intensity for Participant 1, which was estimated to be at least 2,750 teaching episodes for the entirety of treatment.

60-word /s/ probe

Participant 1's progress, shown in Figure 1 below, demonstrates the change in performance across the S Probes administered in the initial testing phase, throughout treatment at five-hour intervals, and in the final testing phase following treatment. During initial assessment, Participant 1 produced an average of 1.33 words correctly across three repetitions of the 60-word probe containing /s/ in initial and final position for an

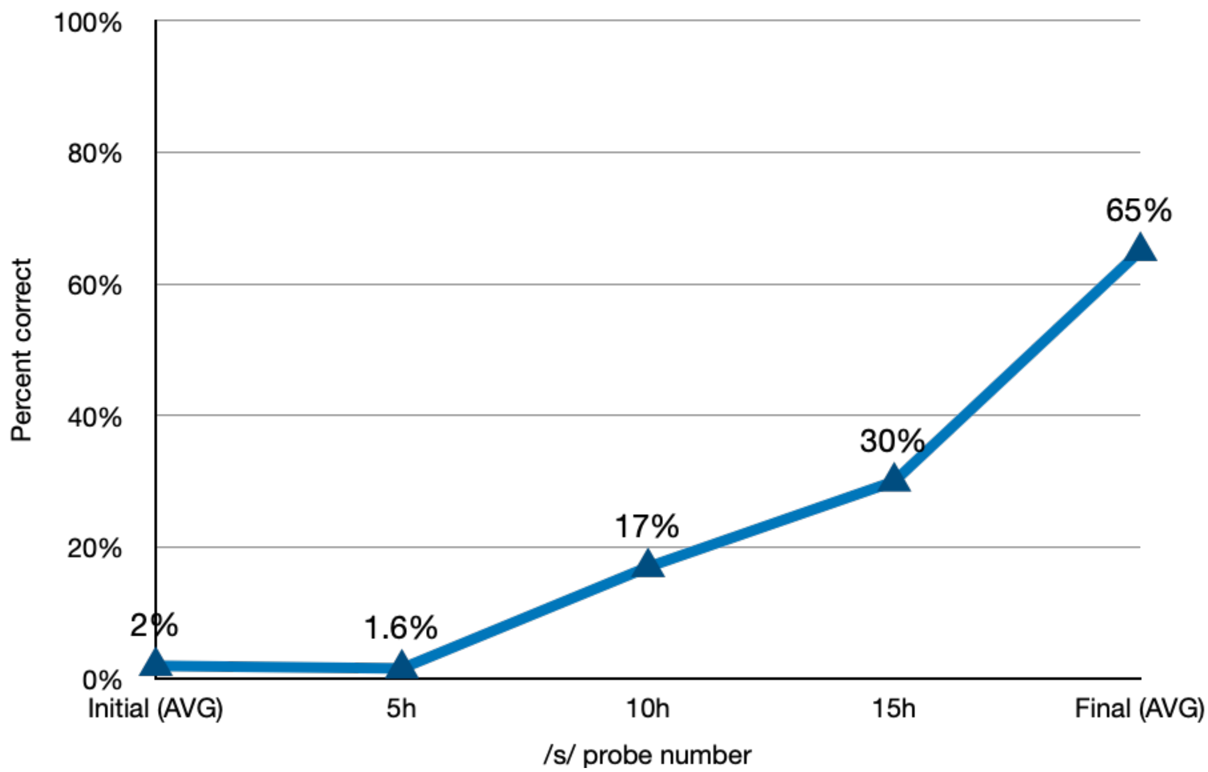


Figure 1: Participant 1 demonstrated an increase in /s/ production accuracy from 2% to 65% accuracy throughout the course of his treatment program.

accuracy of 2%. As therapy progressed, there was a gradual increase in accuracy for each probe. Participant 1's final average accuracy across the three final /s/ probes was 38 out of 60 for an accuracy of 63%.

Overall, Participant 1 demonstrated an increase in /s/ production accuracy of 61% from initial assessment to final assessment on the 60-word probes. He demonstrated a higher level of accuracy in syllable-final position (75%) than syllable-initial position (64%). Of the syllable-initial errors, 93% of the errors included a two- or three-element /s/ cluster, with three-element clusters eliciting the lowest accuracy.

Untreated /s/ probe

Participant 1 also completed a probe containing 14 target /s/ productions in syllable onset and coda positions of ten untreated academic vocabulary words after each hour of treatment was complete. Due to researcher error, three /s/ probes were not obtained during the first three weeks of treatment, so the performance represented in the data does not include the first three weeks. Participant 1's accuracy remained relatively stable throughout therapy, scoring a maximum of one out of 14 correct or 7% accuracy. The low accuracy demonstrated by Participant 1 is hypothesized to be impacted by the inclusion of academic vocabulary in the untreated probes. The academic vocabulary required a greater level of focus on expressive vocabulary skills, reducing their attention on executing an accurate motor plan. One of the important elements of SATPAC is the use of nonwords to limit previously learned incorrect motor plans. The introduction of the academic vocabulary while the Participant still used this errored motor plan might have led to learning an incorrect production of the new words.

It should be noted that the changes in accuracy between the 60-word S Probe and the 10-word untreated /s/ probe did not follow similar patterns, and it is hypothesized that this could be the result of increased frequency of the untreated probes caused the participant to become overly familiar with the words in the probe. This familiarity could have resulted in a reduction of the participant's focus and attention, decreasing opportunities for growth and accurate productions. The S Probe was administered less frequently, which served to maintain the novelty of the word targets and encouraged increased focus from the participant. Also, the inclusion of academic vocabulary in the untreated word probe forced the participant to expend more cognitive resources recalling the vocabulary used in the probe. Conversely, the 60-word probe contained more age-appropriate vocabulary, which might have reduced the cognitive load, allowing the participant to focus on production accuracy. Figure 2 demonstrates Participant 1's production accuracy on the untreated /s/ probe throughout his treatment program.

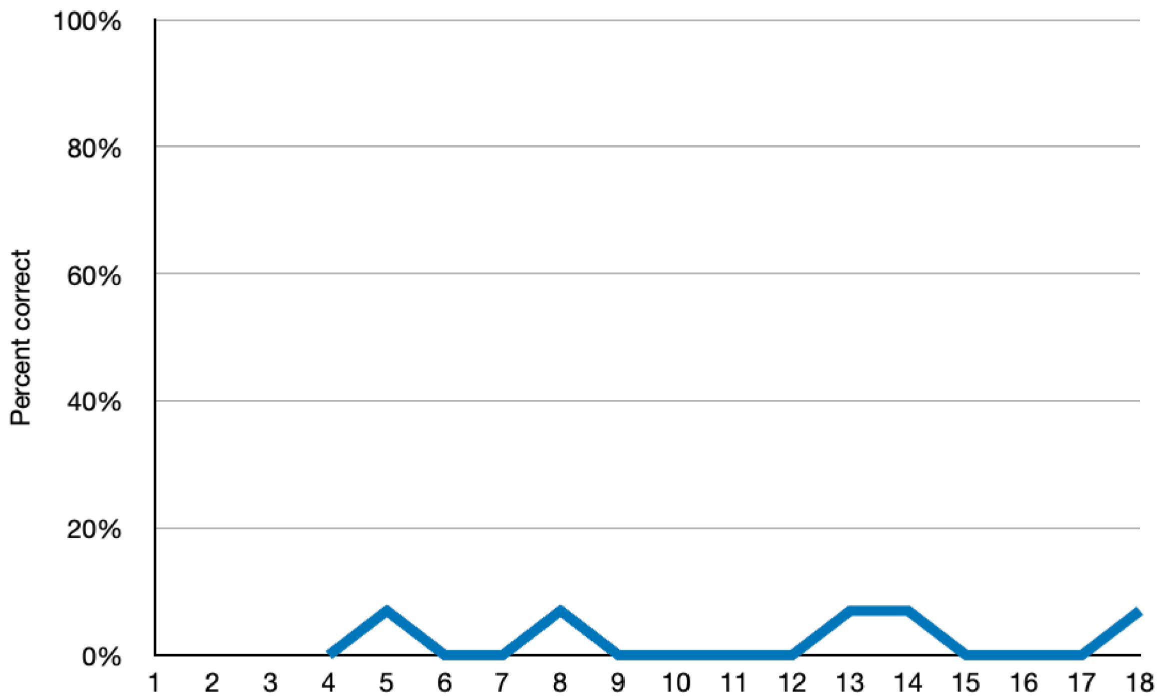


Figure 2: Participant 1 completed 15 10-word untreated /s/ probes with a peak accuracy of one out of 14 possible or 7%.

Effect Size Calculation

To establish the relative magnitude of the generalization gains elicited by the intervention program, the treated phoneme accuracy values from each of the preintervention and post-intervention S Probes were put into the online Tau-*U* Calculator (Vannest et al., 2016) receiving a value of Tau = 1.000, p = 0.008. A Tau-U value of 0.8

or higher demonstrates a large effect size of the treatment. Thus, the null hypothesis can be rejected with a p value < .05. The data shows that for Participant 1, the increase in /s/ production accuracy from initial assessment to final assessment on the S Probe was statistically significant with a large effect size.

Participant 2

Participant 2 completed 51 sessions, for 17 treatment hours, roughly three times per week for 20 minutes each. Due to cancellations by the participant's family, these sessions were spread out across 27 weeks.

Intervention Intensity

Across 17 hours of treatment, Participant 2 received an average dose of 80 teaching episodes for each 20-minute session which occurred three times weekly. The weekly dose provided to Participant 2 was 240 teaching episodes for each hour of treatment. This allows the SLP to calculate the total intervention intensity for Participant 2, which was estimated to be greater than 4,080 teaching episodes for the entirety of treatment.

60-word /s/ probe

Participant 2's progress, shown in Figure 3 below, demonstrates the change in performance across the S Probes administered in the initial testing phase, throughout treatment at five-hour intervals, and in the final testing phase following treatment. During initial assessment, Participant 2 produced an average of 9 words correctly across three repetitions of the 60-word probe containing /s/ in initial- and final-syllable position for an accuracy of 13%. As therapy progressed, Participant 2's accuracy plateaued and then sharply increase in accuracy between the 10- and 15-hour probes. Participant 2's final averaged /s/ production accuracy across the three S Probes was 51.33 out of 60 or

86% accurate.

Overall, Participant 2 demonstrated an increase in accuracy of 73% from initial assessment to final assessment on the 60-word probes. Participant 2 demonstrated a similar level of accuracy in syllable-final positions (82%) and syllable-initial positions (87%). Of the syllable-initial errors, most errors were produced on the /skw/ and /skr/ clusters, which each appeared three times in the probe.

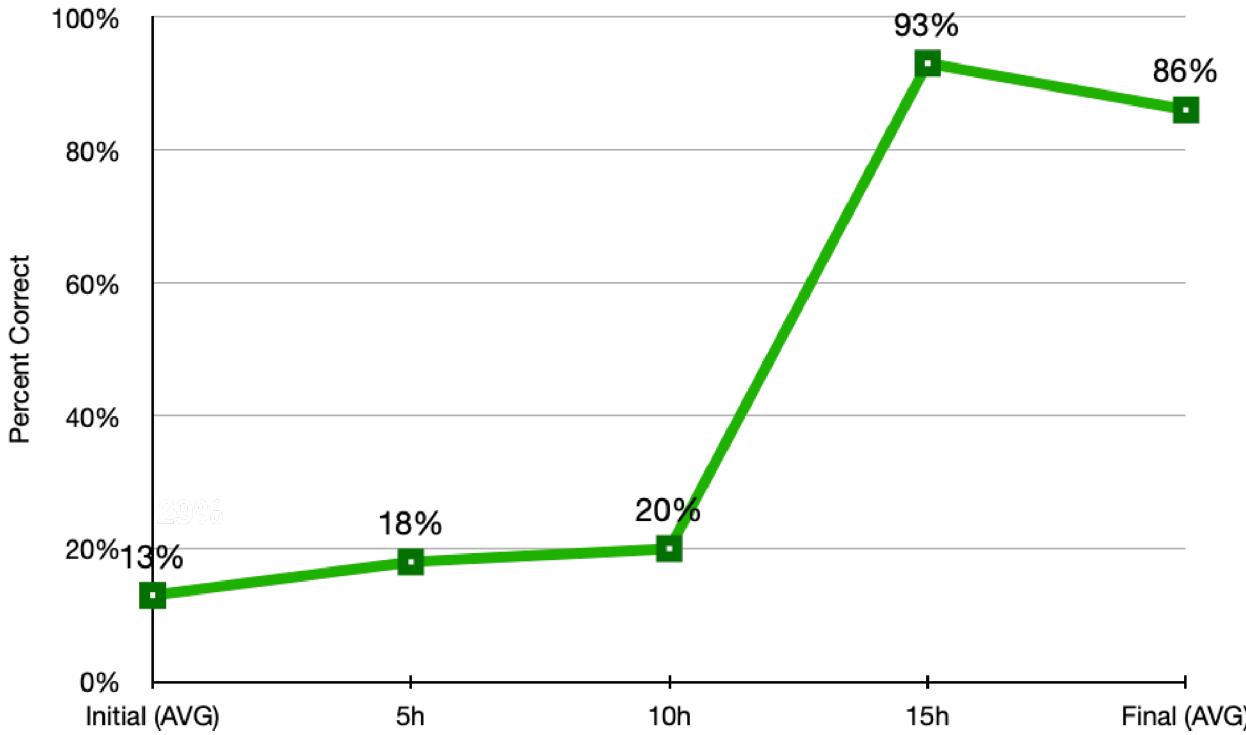


Figure 3: Participant 2 demonstrated an increase in /s/ production accuracy from 13% to 86% accuracy throughout the course of his intervention program.

Untreated /s/ probe

Participant 2 also completed a probe containing /s/ in initial and final positions of ten untreated academic vocabulary words after each hour of treatment was complete. Due to researcher error, two /s/ probes were not obtained during the first two weeks of treatment, so the performance represented in the data does not include the first two weeks. Participant 2's accuracy gradually climbed as therapy progressed reaching a peak after 14 weeks then remaining relatively high. The accuracy in the 10-word untreated probe matches closely with the progress made by Participant 2 in the 60-word /s/ probe. Figure 4 demonstrates Participant 2's change in accuracy during therapy.

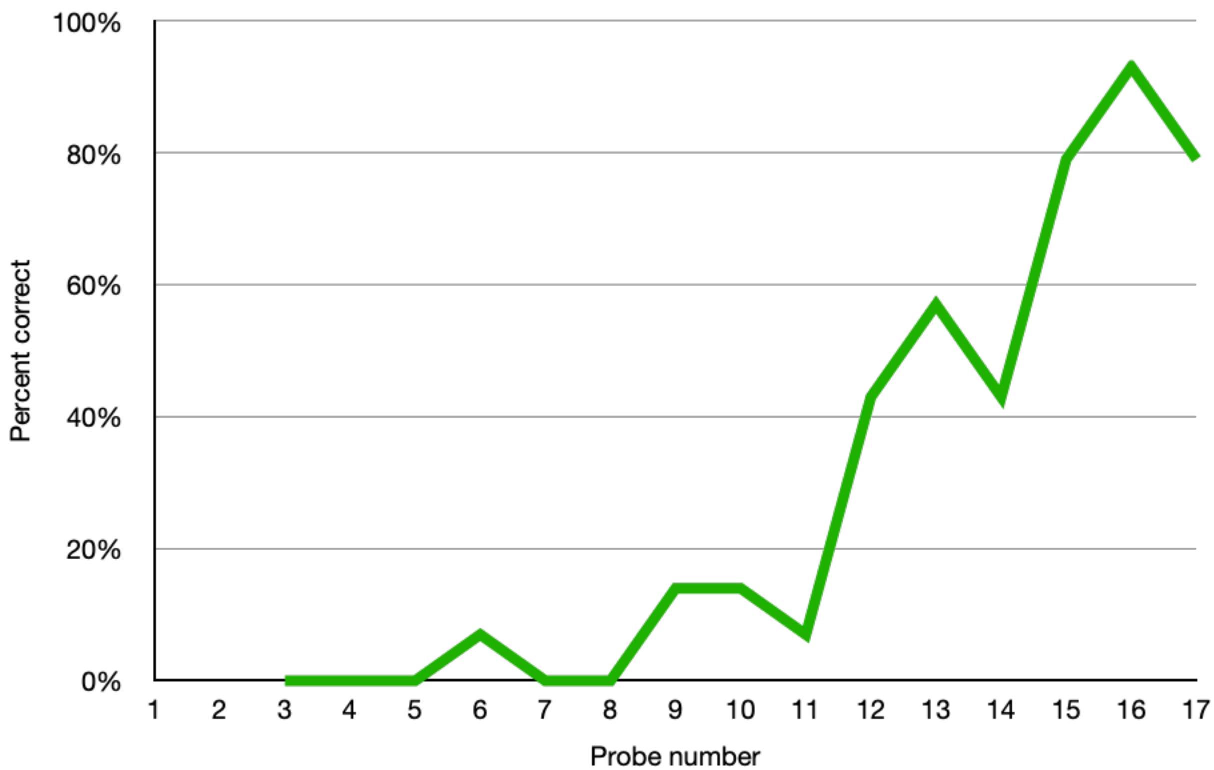


Figure 4: Participant 2 completed 15 10-word untreated /s/ probes with a peak accuracy of 13 out of 14 possible or 93%.

Effect Size Calculation

To establish the relative magnitude of the intervention phoneme generalization gains, the treated phoneme accuracy values from each of the pre-intervention and postintervention speech probes were put into the online Tau-*U* Calculator (Vannest et al., 2016) receiving a value of Tau = 1.000, p = 0.002. A Tau-U value of 0.8 or higher demonstrates a large effect size of the treatment. Thus, the null hypothesis can be rejected with a p value less than .05. The data shows that for Participant 2, the increase in accuracy from initial assessment to final assessment on the S Probe was statistically significant with a large effect size.

Participant 3

Participant 3 completed 34 sessions, for 17 hours of treatment, roughly two times per week for 30 minutes each. Due to cancellations by the participant's family, these sessions were spread out across 27 weeks.

Intervention Intensity

Across 17 hours of treatment, Participant 3 received an average dose of 100 teaching episodes for each 30-minute session which occurred two times weekly. The weekly dose provided to Participant 3 was 200 teaching episodes for each hour of treatment. This allows the SLP to calculate the total intervention intensity for Participant 3, which was estimated to be greater than 3,400 teaching episodes for the entirety of treatment.

60-word /s/ probe

Participant 3's progress, shown in Figure 5 below, demonstrates the change in performance across the S Probes administered in the initial testing phase, throughout treatment at five-hour intervals, and in the final testing phase following treatment. During initial assessment, Participant 3 produced an average of 22 words correctly across three repetitions of the 60-word probe containing /s/ in initial and final position for an accuracy of 38%. As therapy progressed, Participant 3's accuracy rose rapidly to reach a peak level of accuracy (98%) where it remained for the remainder of treatment. Participant 3's final average accuracy across the three final S Probes was 58.67 out of 60 for an /s/ production accuracy of 98%.

Overall, Participant 3 demonstrated an increase in /s/ production accuracy of 60% from initial assessment to final assessment on the 60-word probes. Participant 3 demonstrated a similar level of accuracy in syllable-final positions (100%) and syllableinitial positions (96%). Of the syllable-initial errors, the majority were produced on threeelement consonant clusters such as /spl/ or /skw/.

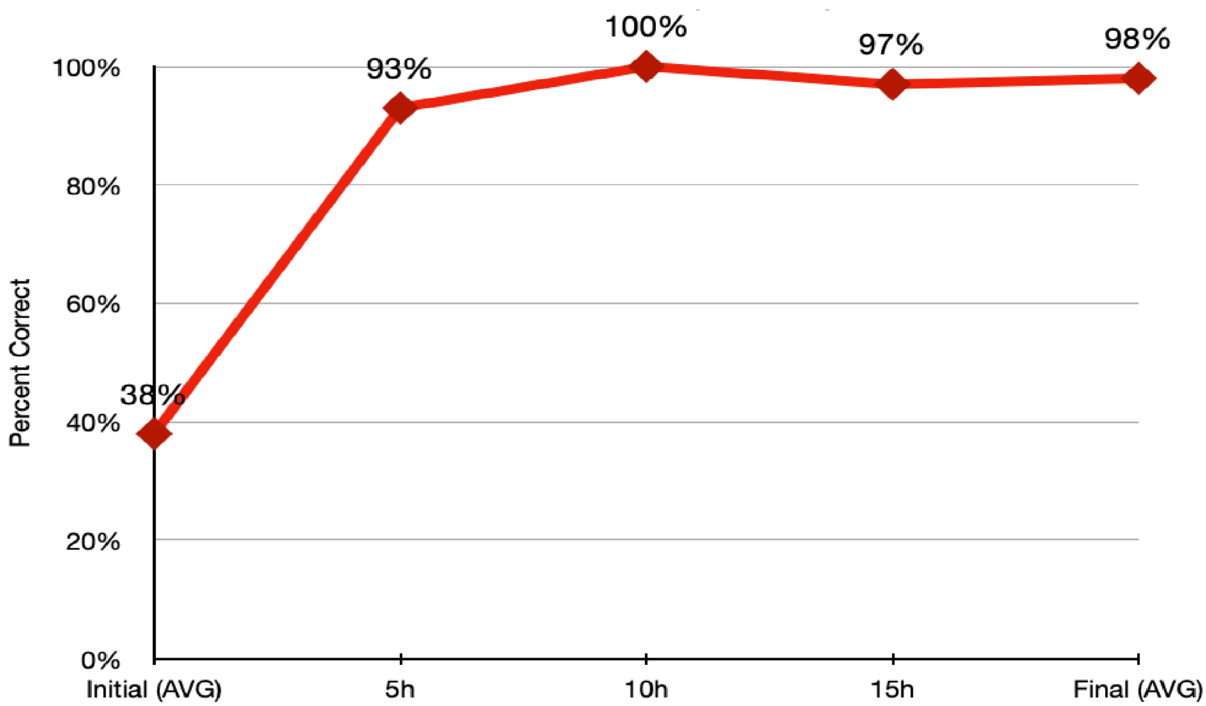


Figure 5: Participant 3 demonstrated an increase in /s/ production accuracy from 38% to 98% accuracy throughout the course of his intervention program.

Untreated /s/ probe

Participant 3 also completed a probe containing /s/ in syllable-initial and syllable-final positions one time after each hour of treatment was administered. Due to researcher error, two /s/ probes were not obtained during the first two weeks of treatment, so the performance represented in the data does not include the first two weeks. Participant 3's accuracy rose rapidly, which was consistent with the progress observed on the S Probe. Once 100% accuracy was reached, Participant 3 remained at that accuracy level for the remainder of therapy. Figure 6 demonstrates Participant 3's change in accuracy during therapy.

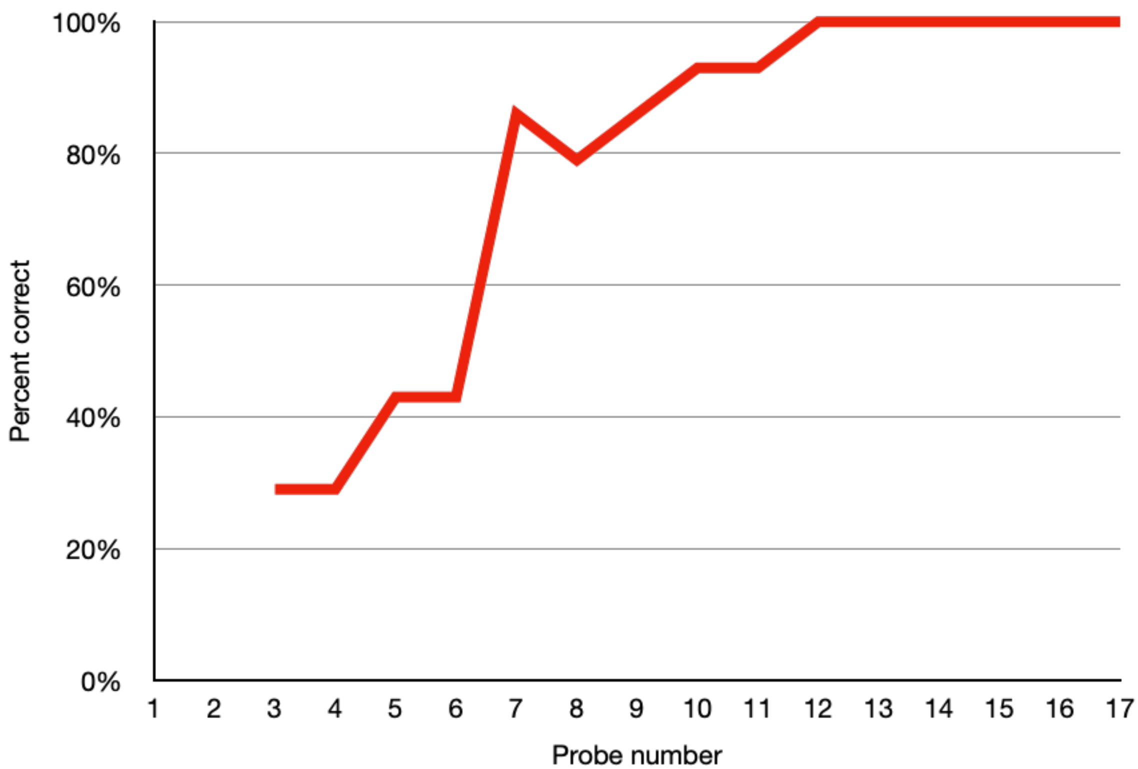


Figure 6: Participant 3 completed 15 10-word untreated /s/ probes with a peak accuracy of 14 out of 14 possible or 100%.

Effect Size Calculation

To establish the relative magnitude of the intervention phoneme generalization gains, the treated phoneme accuracy values from each of the pre-intervention and postintervention speech probes were put into the online Tau-*U* Calculator (Vannest et al., 2016) receiving a value of Tau = 1.000, p = 0.002. A Tau-U value of 0.8 or higher demonstrates a large effect size of the treatment. Thus, the null hypothesis can be rejected with a p value less than .05. The data shows that for Participant 3, the increase in accuracy from initial assessment to final assessment on the 60-word /s/ probe was statistically significant with a large effect size.

Table 1: All three participants demonstrated significant gains on the 60-word /s/ probe. Participants 2 and 3 both demonstrated significant gains on the 10-word /s/ probe.

	Participant 1	Participant 2	Participant 3
Dose frequency and Session length	2x/week, 30 minutes	3x/week, 20 minutes	2x/week, 30 minutes
Total Intervention Intensity	2750 trials	4080 trials	3400 trials
Initial 60-word /s/ probe	2%	13%	38%
Final 60-word /s/ probe	65%	86%	98%
Change in accuracy	**+63%**	**+73%**	**+60%**
Initial 10-word /s/ probe	0%	0%	29,
Final 10-word /s/ probe	7%	79%	100%
Change in accuracy	**+7%**	**+79%**	**+71%**
Tau-U	1.00	1.00	1.00

Effect Size	**Large**	**Large**	**Large**

Summary

All three participants demonstrated large effect sizes with a Tau-U value greater than 0.8 with statistically significant ($p<0.01$) improvement in their /s/ production accuracy on the 60-word /s/ probe between initial assessment and final assessment (Table 1). Each of these results demonstrate the positive effect of using SAPTAC as a therapy technique for remediation of dentalized /s/.

Discussion

The goal of this study was to examine the impact of dose frequency and session length on remediation of dentalized /s/. It was hypothesized that Systematic Articulation Training Program Accessing Computers (SATPAC) would effectively remediate misarticulation of /s/. Additionally, it was hypothesized that there would be no difference in the results of providing therapy 3x/week for 20 minutes when compared to 2x/week for 30 minutes. The findings of this study support the hypothesis that SATPAC is effective, eliciting a statistically significant improvement in /s/ accuracy in three children. This study also found that there was no difference between providing intervention three times per week for 20 minutes when compared to providing intervention two times per week for 30 minutes.

Principles of Motor Learning

SATPAC utilizes practice and feedback conditions from the principles of motor learning to facilitate change in misarticulated sounds. Each phase of this intervention approach integrates the principles of motor learning to change how the participant produces /s/ and /z/. At the beginning of the program, in the placement phase, the practice variability is constant allowing for the participant to learn a consistent motor plan before the variability of the target is increased. During this phase the SLP provides specific feedback using knowledge of performance (information about articulator movement) that allows the participant to focus on placement instead of a specific sound.

Throughout the establishment phase and into the practice phase, the variability of practice increased, thus increasing the complexity of the production. As therapy moves through this progression, the SLP alters feedback and practice elements to ensure the participant remains in the zone of proximal development (Vygotsky, 1978). In the practice phase and into generalization, the target words and facilitating contexts for /s/ increases practice variability and knowledge of performance creating a more realistic and generalizable environment.

Gentile's taxonomy (Gentile, 1972) is a multidimensional taxonomic grid for classifying the complexity of a physical activity. "The environment context is sub divided into a closed environment (stationary regulatory) or open environment (in-motion regulatory) combined with either the performance condition remaining constant (nointertrial variability) or differing each trial (intertrial variability)" (Kraft et al., 2015, p. 9) Targeting speech sounds limits the use of Gentile's taxonomy, but the general structure described by Gentile follows closely with the principles of motor learning and SATPAC. The progression of SATPAC follows closely with Gentile's taxonomy, beginning with ensuring the articulators into the correct position (placement phase), then increasing the intertrial variability from placing the tongue at the alveolar ridge, to moving the tongue from that position into a different position. This builds a solid foundation for learning a new accurate motor plan. As therapy continues, the intertrial variability is increased by providing different contexts and tongue locations for it to move to the target sound (e.g., Move from a velar position for /g/ to an alveolar position for /s/, then move from an interdental position for /th/ to an alveolar position for /s/). This variability allows the participant to demonstrate motor learning in a variety of contexts.

In the present study, the principles of motor learning were an effective guide for increasing the accuracy of /s/ and /z/ production. Each participant demonstrated accuracy improvement and an updated motor plan for their previously errored plan. As the participant increased in accuracy for each phase, practice variability increased creating new facilitative contexts for the target sound. As each participant progressed through the stages, the level of feedback transitioned from primarily knowledge of performance (e.g., “Your tongue was not pointed, don’t forget to smile”) into knowledge of results (e.g., “That one sounded just right”).

Intervention Intensity

Intervention intensity is the combination of dose frequency, dose form, total intervention duration, dose, and cumulative intervention intensity (Warren et al. 2007). Cumulative intervention intensity is the dose x dose frequency x total intervention time which results in a total intensity over the course of the intervention (e.g., 100 trials x 3 sessions/week x 10 weeks = 3000 trials). The findings of this research showed that providing intervention three times per week for 20 minutes resulted in a higher cumulative intervention intensity, when compared to providing intervention two times per week for 30 minutes.

A possible cause of Participant 2 receiving a greater cumulative may be a higher level of participant compliance. It is hypothesized that the increase in weekly dose for the participant receiving therapy three times per week for 20 minutes was caused by a reduction in fatigue as the session continued. The SLP noted a slight decline in performance and engagement with the session between 15 and 20 minutes. With longer sessions, the participants still received therapy for an additional 10-15 minutes after reaching the point of fatigue. With three 20-minute sessions, the participant is receiving more therapy while they are “fresh” than the participants receiving two 30-minute sessions. Even with a large difference in cumulative intervention intensities across children, each participant demonstrated significant gains in /s/ accuracy. To be clear, the lower cumulative intervention intensity in the group receiving therapy twice a week for 30 minutes was not related to a decrease in intervention efficacy. Instead, this small sample size provides limited evidence that shorter, more frequency sessions might be more efficient than fewer, longer intervention sessions.

Clinical implications

Dentalization of the /s/ and /z/ sounds (i.e., frontal or dental lisps) is the most common production error in the English language (Shriberg, 2019). Many school based SLPs will treat children that demonstrate a primary error of dentalization of /s/. Previously, the most applied approach for remediating dentalized /s/ was the traditional approach developed by Van Riper (1972) which demonstrated mixed results and difficulty with maintenance and generalization (Ruscello, 1995). With the inconsistent success of the traditional approach, determining efficacy of SATPAC could provide an alternative approach to treating this error. Given the efficient remediation of dentalized

/s/ in the present study, SATPAC has promising evidence for future clinical use. SATPAC is effective for remediating /s/ and /z/ because it creates a framework for relearning an errored motor plan using the principles of motor learning and allowing the SLP to adjust the difficulty of the task to remain within Vygotsky's zone of proximal development (1978).

In addition, the findings of this research provide additional information for SLPs when making service delivery decisions. The SLP can choose an intervention intensity that most effectively fits their workload. The findings do allow for flexibility, but they also demonstrate that therapy following the typical model (2x/week for 30 minutes) remains a viable choice for providing therapy. That being said, the dosage achieved in this study may be unrealistic for school based SLPs. Due to high caseloads, school based SLPs often provide intervention in groups. Byers & colleagues (2021) reported that 5-minute individual sessions conducted three times per week was more effective than a 30minute group session conducted twice per week. Sacks (2013) implemented SATPAC in 10-minute intervention sessions with a high level of success. The findings of this study demonstrate an increase in dosage for children receiving multiple, shorter individual sessions. Treatment may be more effective if the SLP provides intervention in multiple shorter sessions as compared to a single, weekly longer group session.

Telepractice

In 2004, ASHA approved the use of telepractice for providing speech therapy (ASHA, 2004) which opened the possibility of providing therapy to remote areas. Eight years after telepractice was approved by ASHA, a survey by Tucker (2012) found that only 1.8% of SLPs reported using telepractice to provide intervention which matches closely with a survey by ASHA (2011) which reported only 2.3% of SLPs using telepractice. The pandemic caused by Covid-19 pushed many reluctant SLPs into telepractice.

While the service delivery aspect of telepractice has been examined in multiple studies, the evidence base for SSD intervention through telepractice is lacking. GrogenJohnson and colleagues (2011) examined the accuracy and efficacy of SSD treatment, but primarily focused on a phonological approach to SSD instead of a motor-based treatment approach, finding that providing phonological intervention is effective over telepractice. SATPAC, being a motor-based approach, has multiple components that become more difficult to address when provided over telepractice.

For an intervention to effectively change a motor plan, a client needs instruction on the proper location of the articulators, and then information about their success with those instructions. Providing information about their success with accurate articulator placement is one example of how deeply the principles of motor learning are ingrained into this intervention approach. Depending on what is most effective for the client, visual cues, verbal cues, tactile cues, kinesthetic cues, or a combination of all four should be used to guide the client through an accurate motor plan. While in person, providing these cues is a common part of many therapy approaches. However, in telepractice the SLP is limited in what visual cues can be provided and the SLP is unable to directly provide tactile cues to the client.

The establishment or placement phase of SATPAC places heavy emphasis on tactile cues and physical manipulation of the tongue and jaw using tongue depressors. These cues establish the foundation for learning the new motor plan and requires materials, knowledge of oral structures, and efficient oral observation. In a virtual telepractice environment, the SLP is unable to directly provide the materials or efficiently observe and manipulate articulator movement. As a result, providing intervention over telepractice required some adjustments that may have delayed the acquisition of the new motor plan. Sacks (2013) reported completing the placement phase with each participant in one week. It is hypothesized that the ability to provide direct tactile cues and manual manipulation of the tongue greatly improves the speed of acquisition. For Participants 1 and 2, the placement phase took three weeks, while Participant 3 was able to acquire the correct placement within one week. The variation in the speed of acquisition may be the result of the age difference between the participants. With Participant 3 being older than participants 1 and 2, he might have had more motor control and a greater understanding of articulator placement instructions than the younger two participants.

A small number of tongue depressors was mailed to all participants, which were then used during the telepractice sessions. During the sessions, the significant anatomical landmarks and correct tongue placement was discussed with each participant and the clinician modeled the movements for each child. Unfortunately, there was not an effective way to look into the client's mouth during placement to ensure that the client was finding the correct articulator location. Having an in-person facilitator sitting next to the child during the session would have created the opportunity for an adult to manipulate the tongue and clearly observe oral structures. An in-person facilitator would also learn the correct placement of the articulators and allow for increased motor plan feedback containing both knowledge of performance and knowledge of results outside of intervention session time. On top of assisting with articulator placement, tactile cues, and feedback, an adult facilitator would have likely increased the focus and engagement of the participant.

Another significant barrier to providing therapy over telepractice is managing participant behaviors. There was not consistent parental engagement in the sessions to support the therapy process or the participants' learning. Without parent involvement in the sessions, the clinician had a limited ability to prevent or stop behavior that was detrimental to therapy. For example, when a participant became distracted, the SLP had no avenue to remove the distraction or to limit the participant's interaction with the distracting object. Also, participants frequently left the room that the computer was in, disrupting the therapy session. In addition to participant behavior, each participant had siblings that would frequently interject into the therapy session further derailing the participant's focus. To account for this in the future, SLPs providing speech intervention via telepractice should ensure that an adult facilitator will be available during therapy sessions to help with behavior management for the child, as well as prevent other children from distracting from the therapy session. SLPs should also recommend that therapy occur in a private room that is not accessible to other family members for the duration of the session. Given the barriers to providing motor-based intervention through telepractice, SLPs should consider how these barriers will be addressed before beginning intervention.

While it is not appropriate for every SLP or every client, SLPs may choose to provide intervention over telepractice if that decision provides the most convenient service delivery for the SLP or the family. Scheduling is one of the primary reasons that SLPs may choose to provide intervention over telepractice due to increased convenience for the family. Telepractice allows SLPs to adjust the intervention intensity to fit the needs of the client without increasing time spent traveling to an in-person therapy room. With an increase in convenience, it could be expected that client attendance would remain consistently high. Unfortunately, in the present study the children and their families were not consistent in their session attendance. It is likely that the participants' schedule flexibility, parent engagement, and summer vacations had a negative impact on their attendance. The flexibility of telepractice increases convenience but can make forming a consistent routine difficult for families. Also, having a lower dose frequency reduces the consistency of attending therapy, whereas a higher intensity can make therapy attendance more routine and easier to remember. Without a consistent routine of therapy attendance, the likelihood of missed sessions increases greatly. With increased parent engagement in the sessions, it is hypothesized that parents will be more involved in maintenance of the schedule. Finally, the variability of summer schedules could make it more difficult for families to consistently attend summer intervention sessions as compared with school-year sessions.

In this study, independent home programing was not provided to the participants to complete outside of the therapy sessions because the level of participant engagement with home exercises could not be controlled. However, with adequate instruction, home programming has demonstrated a positive effect on the progress made in speech therapy (Lawler et al., 2013). For example, Sacks (2013) provided home programming throughout his SATPAC study beginning in the placement phase and continuing through the practice phase. He reported providing lists to practice that the client had previously demonstrated competence by scoring 90% accuracy. Generally, the increased practice clients have with home programing is expected to have a positive impact on the speed of target sound remediation.

SATPAC Outcomes

SATPAC was initially designed to be used in schools by SLPs managing large caseloads. Children with SSD typically represent nearly 39% of a typical school based SLP's caseload (ASHA, 2020). As dentalization of /s/ and /z/ is the most common production error in the English language (Shriberg, 2019), school based SLPs are likely to see children who demonstrate this error pattern. The present study may have wide reaching impacts on the speed and efficiency with which SLPs can treat /s/ dentalization. In the present study, each participant demonstrated significant gains in /s/ accuracy in 17 or 18 hours respectively. Ruscello (1995) reports requiring nearly double that amount of time (i.e., 32 hours) when using the traditional treatment method to remediate this dentalization error. The speed at which remediation can occur, especially when compared to traditional treatment, should encourage SLPs treating children with misarticulation of /s/ and /z/ to consider the use of SATPAC in their practice.

The data showed that the application of SATPAC is effective for remediating dentalized /s/ in 6- to 8-year-old children. This finding is consistent with existing literature examining the efficacy of SATPAC (Sacks and Shine, 2004; Sacks, Flipsen, & Neils-Strunjas, 2013; Flipsen and Sacks, 2015). Previous research conducted on the effectiveness of SATPAC either examined the dose frequency (Sacks et al., 2013) or session dose (Flipsen & Sacks, 2015) demonstrating a lack of research that evaluates both dose and dose frequency, which are both instrumental for determining intervention intensity. The present study provides independent support for the efficacy of SATPAC that does not include the creator of the program, as well as increased methodological rigor with information on intervention intensity.

Even with the restrictions presented by providing SATPAC over telepractice, in the right situation with adequate caregiver involvement, and willingness to implement supervised home programming, SATPAC was an effective speech intervention program for remediating dental /s/ productions.

Limitations

While this study provides evidence supporting the use of SATPAC over telepractice in a variety of intensities, there are limitations to these findings. First, the sample size used in this multiple-baseline single-subject design research program is only three participants. The heterogeneity of children with speech sound disorders (SSD) brings into question the representativeness of the sample. All three participants were from the same family (i.e., two brothers and a cousin), thus limiting the representativeness even more. All three participants were also male, which represents a large portion of all SSD, but further limits the sample representativeness.

Another limitation of this study is the inconsistent attendance by the participants' families. Ideally, intervention would be applied for 18 consecutive weeks, but it was spread out over 28 weeks resulting in multiple breaks of greater than two weeks. The lack of consistency likely reduced the efficacy of treatment as well as reducing the likelihood of replicating the results. With long breaks between treatment sessions, and no home programming, the participants completed going long periods of time without practicing the target sound or receiving feedback. The efficacy of the intervention program is greatly diminished without the participant receiving consistent information about the accuracy of the motor plan they are using. If this information is unavailable, then no motor learning can occur for the participant (Maas et al., 2008).

The participants were also unavailable for post-intervention maintenance probes to determine if progress was maintained or continued to improve outside of the treatment program. The inability to obtain maintenance samples limited the ability to measure the potential long-term effects of the treatment program.

Conclusion

Three children with dentalized /s/ productions demonstrated significant improvement of /s/ accuracy when provided with a speech intervention program via telepractice. Service delivery via telepractice has been primarily examined in providing phonological intervention, but there has been limited evidence for the efficacy of providing motorbased intervention via telepractice. This study supports the use of a motor-based intervention, SATPAC, over telepractice. Intervention provided twice a week for 30 minutes and three times a week for 20 minutes resulted in similar intervention outcomes suggesting that both intervention session schedules can elicit change in children's speech production. Interestingly, the higher dosage achieved with the participant receiving more frequent but shorter sessions suggests that shorter sessions may be more efficient in eliciting more motor-based practice than longer sessions. Ultimately, providing motor-based speech intervention like SATPAC over telepractice can be effective for the remediation of dentalized /s/ and /z/.

References

Allen, M. M. (2013). Intervention Efficacy and Intensity for Children With Speech Sound Disorder. Journal of Speech, Language, and Hearing Research, 56(3), 865-877. https://doi.org/doi:10.1044/1092-4388(2012/11-0076)

American Speech-Language-Hearing Association. (2005). Speech-language pathologists providing clinical services via telepractice: position statement [position statement]. https://www.asha.org/policy/pp2004-00191/.

Baker, E. (2012). Optimal intervention intensity. International Journal of Speech-Language Pathology, 14(5), 401-409. https://doi.org/10.3109/17549507.2012.700323

Baker, E., & McLeod, S. (2011). Evidence-Based Practice for Children With Speech Sound Disorders: Part 1 Narrative Review. Language, Speech, and Hearing Services in Schools, 42(2), 102-139. https://doi.org/doi:10.1044/0161-1461(2010/09-0075)

Brandel, J., & Loeb, D. F. (2011). Program Intensity and Service Delivery Models in the Schools: SLP Survey Results. Language, Speech, and Hearing Services in Schools, 42(4), 461-490. https://doi.org/doi:10.1044/0161-1461(2011/10-0019

Busk, P. L., & Serlin, R. C. (1992). Meta-analysis for single-case research. In T.R. Kratochwill & J.R. Levin (eds.), Single-case research design and analysis (pp. 187–212). Lawrence Erlbaum.

Byers, B. A., Bellon-Harn, M. L., Allen, M., Saar, K. W., Manchaiah, V., & Rodrigo, H. (2021). A Comparison of Intervention Intensity and Service Delivery Models With School-Age Children With Speech Sound Disorders in a School Setting. Language, Speech, and Hearing Services in Schools, 52(2), 529-541. https://doi.org/doi:10.1044/2020_LSHSS-2000057

Coxhead, A. (2000). A new academic word list. TESOL Quarterly, 34(2), 213–238. https://doi.org/10.2307/3587951

Cummings, A., & Barlow, J. A. (2011). A comparison of word lexicality in the treatment of speech sound disorders. Clinical Linguistics & Phonetics, 25(4), 265–286. https://doi.org/10.3109/02699206.2010.528822

Cummings, A., Giesbrecht, K., & Hallgrimson, J. (2020). Intervention dose frequency: Phonological generalization is similar regardless of schedule: Child Language Teaching and Therapy. https://doi.org/10.1177/0265659020960766

Cummings, A., Hallgrimson, J., & Robinson, S. (2019). Speech intervention outcomes associated with word lexicality and intervention intensity. Language, Speech, and Hearing Services in Schools, 50, 83–98. https://doi.org/10.1044/2018_LSHSS-18-0026 Derdemezis, E., Vorperian, H. K., Kent, R. D., Fourakis, M., Reinicke, E. L., & Bolt, D. M. (2016). Optimizing Vowel Formant Measurements in Four Acoustic Analysis Systems for Diverse Speaker Groups. American Journal of Speech-Language Pathology, 25(3), 335–354. https://doi.org/10.1044/2015_AJSLP-15-0020

Espy-Wilson, C. Y., Boyce, S. E., Jackson, M., Narayanan, S., & Alwan, A. (2000). Acoustic modeling of American English /r/. The Journal of the Acoustical Society of America, 108(1), 343–356. https://doi.org/10.1121/1.429469

Flipsen, P., & Sacks, S. (2015). Remediation of Residual /r/ Errors: A Case Study Using the SATPAC Approach. Perspectives on School basedIssues, 16(3), 64–78. ***https://doi.org/10.1044/sbi16.3.64***

Gentile, A. M. (1972). A working model of skill acquisition with application to teaching. Quest, 17(1), 3-23.

Gierut, J. A. (2001). Complexity in phonological treatment: Clinical factors. Language, Speech, and Hearing Services in Schools, 32(4), 229–241. https://doi.org/10.1044/01611461(2001/021)
Gierut, J. A. (2007). Phonological complexity and language learnability. American Journal of Speech-Language Pathology, 16(1), 6–17. https://doi.org/10.1044/1058-0360(2007/003)
Gierut, J. A., Morrisette, M. L., & Dickinson, S. L. (2015). Effect size for single-subject design in phonological treatment. Journal of Speech, Language, and Hearing Research, 58(5), 1464–1481. https://doi.org/10.1044/2015_JSLHR-S-14-0299
Gierut, J. A., Simmerman, C. L., & Neumann, H. J. (1994). Phonemic structures of delayed phonological systems. Journal of Child Language, 21(2), 291–316.
Goldman, R., & Fristoe, M. (2015). Goldman-Fristoe Test of Articulation (3rd ed.). Pearson.
Hegarty, N., Titterington, J., McLeod, S., & Taggart, L. (2018). Intervention for children with phonological impairment: Knowledge, practices and intervention intensity in the UK. International Journal of Language & Communication Disorders, 53(5), 995-1006. https://doi.org/https://doi.org/10.1111/1460-6984.12416
Hegarty, N., Titterington, J., & Taggart, L. (2021). A qualitative exploration of speech-language pathologists 'intervention and intensity provision for children with phonological impairment. International Journal of Speech-Language Pathology, 23(2), 213-224. https://doi.org/10.1080/17549507.2020.1769728
Hitchcock, E. R., Harel, D., & Byun, T. M. (2015). Social, Emotional, and Academic Impact of Residual Speech Errors in School-Aged Children: A Survey Study. Seminars in speech and language, 36(4), 283-294. https://doi.org/10.1055/s-0035-1562911
Kaipa, R., & Peterson, A. M. (2016). A systematic review of treatment intensity in speech disorders. International Journal of Speech-Language Pathology, 18(6), 507-520. https://doi.org/10.3109/17549507.2015.1126640
Khan, L., & Lewis, N. (2015). Khan-Lewis Phonological Analysis (3rd ed.). Pearson.
Kraft, K.P., Steel, K.A., Macmillan, F. et al. Why few older adults participate in complex motor skills: a qualitative study of older adults' perceptions of difficulty and challenge. BMC Public Health 15, 1186 (2015). https://doi.org/10.1186/s12889-015-2501-z
Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012). Age-of-acquisition ratings for 30,000 English words. Behavior Research Methods, 44(4), 978–990. https://doi.org/10.3758/s13428-012-0210-4
Lennes, M. (2003). Collect_formant_data_from_files.praat [Praat Script] [Praat; Praat]. Praat.
Maas, E., Robin, D. A., Hula, S. N. A., Freedman, S. E., Wulf, G., Ballard, K. J., & Schmidt, R. A. (2008). Principles of Motor Learning in Treatment of Motor Speech Disorders. American Journal of Speech-Language Pathology, 17(3), 277-298. https://doi.org/doi:10.1044/10580360(2008/025)
Marian, V., Bartolotti, J., Chabal, S., & Shook, A. (2012). CLEARPOND: Cross-Linguistic EasyAccess Resource for Phonological and Orthographic Neighborhood Densities. PLOS ONE, 7(8), e43230. https://doi.org/10.1371/journal.pone.0043230
McLeod, S., & Baker, E. (2014). Speech-language pathologists' practices regarding assessment, analysis, target selection, intervention, and service delivery for children with speech sound disorders. Clinical Linguistics & Phonetics, 28(7/8), 508-531. https://doi.org/10.3109/02699206.2014.926994
McReynolds, L. V., & Kearns, K. P. (1983). Single-subject experimental designs in communicative disorders. PRO-ED.

Miccio, A. W., Elbert, M., & Forrest, K. (1999). The relationship between stimulability and phonological acquisition in children with normally developing and disordered phonologies. American Journal of Speech-Language Pathology, 8, 347–363.
Rose, Y., & MacWhinney, B. (2014). The PhonBank Project: Data and software-assisted methods for the study of phonology and phonological development. In J. Durand, U. Gut, & G. Kristoffersen (eds.), The Oxford Handbook of Corpus Phonology (pp. 308–401). Oxford University Press.
Namasivayam, A. K., Pukonen, M., Goshulak, D., Granata, F., Le, D. J., Kroll, R., & van Lieshout, P. (2019). Investigating intervention dose frequency for children with speech sound disorders and motor speech involvement. International Journal of Language & Communication Disorders, 54(4), 673-686. https://doi.org/https://doi.org/10.1111/14606984.12472
Nissen, S. L., Peris, M. E., & Tanner, K. (2017). An intensive boot camp approach to the remediation of speech sound disorders: a case report. Speech, Language and Hearing, 22(2), 51-60. https://doi.org/10.1080/2050571X.2017.1376495
Roepke, E., Greenwell, T., & Brosseau-Lapré, F. (2019). Service delivery for children with speech sound disorders: Evidence for the Quick Articulation! model. EBP Briefs.
Ruscello, D. M. (1995). Visual feedback in treatment of Residual Phonological disorders. Journal of Communication Disorders, 28(4), 279-302. https://doi.org/https://doi.org/10.1016/0021-9924(95)00058-X
Shriberg, L. (2019). Clinical Phonetics. Pearson.
Secord, W. A., Boyce, S. E., Donohue, J. S., Fox, R. A., & Shine, R. E. (2007). Eliciting sounds: Techniques and strategies for clinicians (2nd edition). Cengage Learning.
Semel, E., Wiig, E., & Secord, W. (2004). Clinical Evaluation of Language Fundamentals, Preschool—Second Edition (CELF-P2). Pearson.
Sugden, E., Baker, E., Munro, N., Williams, A. L., & Trivette, C. M. (2018). Service delivery and intervention intensity for phonology-based speech sound disorders. International Journal of Language & Communication Disorders, 53(4), 718-734. https://doi.org/https://doi.org/10.1111/1460-6984.12399
Vannest, K. J., & Ninci, J. (2015). Evaluating Intervention Effects in Single-Case Research Designs. Journal of Counseling & Development, 93(4), 403–411. https://doi.org/10.1002/jcad.12038
Vannest, K. J., Parker, R. I., Gonen, O., & Adiguzel, T. (2020). Single case research: Web based calculators for SCR analysis. (Version 2.0) [Web-based application]. Texas A&M University. singlecaseresearch.org
Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes (Cole, M., John-Steiner, V., Scribner, S. & Souberman, E., Eds.). Harvard University Press.
Wales, D., Skinner, L., & Hayman, M. (2017). The Efficacy of Telehealth-Delivered Speech and Language Intervention for Primary School-Age Children: A Systematic Review. International Journal of Telerehabilitation, 9(1), 55–70. https://doi.org/10.5195/ijt.2017.6219. https://doi.org/https://doi.org/10.5195/ijt.2017.6219
Wiig, E., Semel, E., & Secord, W. (2013). Clinical Evaluation of Language Fundamentals—Fifth Edition (CELF-5) (5th ed.). Pearson.
Williams, A. L. (2012). Intensity in phonological intervention: Is there a prescribed amount? International Journal of Speech-Language Pathology, 14(5), 456-461. https://doi.org/10.3109/17549507.2012.688866

AM111-S_Probe

	Orthography	IPA Target	Transcription
1	[tree house]	[ˈtɹiː / ˈhɑʊsǀ]	
2	[messy]	[ˈmɛs̸iːǀ]	
3	[scarf]	[ˈskɑɹf]	
4	[slipper]	[ˈs̸lɪpəɹǀ]	
5	[sprinkle]	[ˈspɹɪŋkəl]	
6	[this]	[ðɪs]	
7	[strong]	[ˈs̸tɹɑŋǀ]	
8	[yes]	[ˈjɛs]	
9	[grass]	[ˈgɹæs]	
10	[sock]	[ˈsɑk]	
11	[vase]	[ˈveɪs]	
12	[spaghetti]	[spəˈgɛtiː]	
13	[splinter]	[ˈsplɪntəɹ]	
14	[spring]	[ˈspɹɪŋ]	
15	[sleeve]	[ˈsliːv]	
16	[smoke]	[ˈsmoʊk]	
17	[stove]	[ˈstoʊv]	
18	[glass]	[ˈglæs]	
19	[six]	[ˈsɪks]	
20	[stripes]	[ˈstɹaɪps]	
21	[caboose]	[kəˈbuːs]	
22	[surprise]	[səˈpɹaɪz]	
23	[split]	[ˈsplɪt]	
24	[smile]	[ˈsmaɪl]	
25	[spraying]	[ˈspɹeɪɪŋ]	
26	[sneeze]	[ˈsniːz]	

27	[swim]	[ˈswɪm]	
28	[scratch]	[ˈskɹæʧ]	
29	[skate]	[ˈskeɪt]	
30	[sweep]	[ˈswiːp]	
31	[splash]	[ˈsplæʃ]	
32	[squeeze]	[ˈskwiːz]	
33	[kiss]	[ˈkɪs]	
34	[sing]	[ˈsɪŋ]	
35	[snail]	[ˈsneɪl]	

1 AM111-S_Probe

36	[space]	[ˈspeɪs]	
37	[sun]	[ˈsʌn]	
38	[skunk]	[ˈskʌŋk]	
39	[spoon]	[ˈspuːn]	
40	[ice]	[ˈɑɪs]	
41	[sleep]	[ˈsliːp]	
42	[hiss]	[ˈhɪs]	
43	[stir]	[ˈstʌɹ]	
44	[snow]	[ˈsnoʊ]	
45	[race]	[ˈɹeɪs]	
46	[star]	[ˈstɑɹ]	
47	[sword]	[ˈsɔɹd]	
48	[sir]	[ˈsʌɹ]	
49	[dress]	[ˈdɹɛs]	
50	[squirrel]	[ˈskwʌɹəl]	
51	[scream]	[ˈskɹiːm]	
52	[string]	[ˈstɹɪŋ]	
53	[sweater]	[ˈswɛtəɹ]	

54	[stop]	[ˈstɑp]	
55	[snake]	[ˈsneɪk]	
56	[smell]	[ˈsmɛl]	
57	[squirt]	[ˈskwʌɹt]	
58	[sled]	[ˈslɛd]	
59	[small]	[ˈsmɑl]	
60	[scribble]	[ˈskɹɪbəl]	

2 AM111-Polysyllabic_Probe

	Orthography	IPA Target	Transcription
1	ambulance	[ˈæmbjələns]	
2	animals	[ˈænəməlz]	
3	banana	[bəˈnænə]	
4	broccoli	[ˈbɹɑkəli]	
5	bulldozer	[ˈbʊlˌdoʊzəɹ]	
6	butterfly	[ˈbʌtəɹˌflɑɪ]	
7	bell pepper	[ˈbɛl ˈpɛpəɹ]	
8	computer	[kəmˈpjutəɹ]	
9	crocodile	[ˈkɹɑkəˌdɑɪl]	
10	cucumber	[ˈkjukəmbəɹ]	
11	dinosaur	[ˈdɑɪnəˌsɔɹ]	
12	echidna	[əˈkɪdnə]	
13	elephant	[ˈɛləfənt]	
14	hamburger	[ˈhæmbəɹgəɹ]	
15	hospital	[ˈhɑsˌpɪtəl]	
16	kangaroo	[ˌkæŋgəˈɹu]	
17	koala	[koʊˈɑlə]	
18	medicine	[ˈmɛdəsən]	
19	microwave	[ˈmɑɪkɹəˌweɪv]	

20	mosquito	[məsˈkitoʊ]	
21	motorbike	[ˈmoʊtəɹˌbaɪk]	
22	octopus	[ˈɑktəˌpʊs]	
23	platypus	[ˈplætəˌpʊs]	
24	policeman	[pəˈlismən]	
25	potato	[pəˈteɪˌtoʊ]	
26	pajamas	[pəˈʤɑməz]	
27	rectangle	[ˈɹɛktæŋgəl]	
28	sausages	[ˈsɑsɪʤəz]	
29	spaghetti	[spəˈgɛtiː]	
30	stethoscope	[ˈstɛθəsˌkoʊp]	
31	tomato	[təˈmeɪˌtoʊ]	
32	triangle	[ˈtɹɑɪˌæŋgəl]	
33	umbrella	[əmˈbɹɛlə]	
34	vegetables	[ˈvɛʤtəbəlz]	
35	zucchini	[zuˈkini]	

1 AM111-Polysyllabic_Probe

36	avocado	[ˌævəˈkɑdoʊ]	
37	caterpillar	[ˈkætəˌpɪləɹ]	
38	cauliflower	[ˈkɑləˌflɑʊəɹ]	
39	escalator	[ˈɛskəˌleɪtəɹ]	
40	helicopter	[ˈhɛlɪˌkɑptəɹ]	
41	pinocchio	[pəˈnoʊkijoʊ]	
42	rhinoceros	[ɹɑɪˈnɑsəɹəs]	
43	television	[ˈtɛləˌvɪʒən]	
44	thermometer	[θəɹˈmɑmətəɹ]	
45	vacuum cleaner	[ˈvækjum ˈklinəɹ]	
46	washing machine	[ˈwɑʃɪŋ mɪˈʃin]	

47	watermelon	[ˈwɑtəɹˌmɛlən]	
48	hippopotamus	[ˌhɪpəˈpɑtəməs]	

2