7-3-2019

The Comparative Efficiency of Speech Sound Interventions That Differ by Delivery Modality: Flashcards Versus Tablet

Krystal Werfel

Marren Brooks

Lisa A. Fitton Ph.D.
University of South Carolina - Columbia, fittonl@mailbox.sc.edu

Publication Info

Postprint version. Published in *Communication Disorders Quarterly*, Volume 42, Issue 1, 2019, pages 31-39.

The comparative efficiency of speech sound interventions that differ by delivery modality: Flashcards versus tablet

Krystal Werfel, Marren Brooks, & Lisa Fitton

APA Citation:

Werfel, K., Brooks, M., & Fitton, L. (2020). The comparative efficiency of speech sound interventions that differ by delivery modality: Flashcards versus tablet. *Communication Disorders Quarterly, 42*(1), 31-39. https://doi.org/10.1177/1525740119859520

Infographic highlighting key findings created by the Written Language Lab (directed by Dr. Krystal Werfel):

https://www.sc.edu/study/colleges_schools/public_health/research/research_areas/communication_sciences_and_disorders/written_language_lab/tabletvflashcardinfo.pdf

Abstract

Although speech-language pathologists increasingly make use of tablets in clinical practice, little research to date has evaluated the effectiveness or efficiency of tablet use for targeting speech sound goals. The three-fold purpose of this study was to compare (a) the effectiveness and (b) the efficiency of speech sound intervention using tablets versus flashcards, as well as (c) child motivation in speech sound intervention when using tablets versus flashcards. Four kindergarten students with at least two similar speech sound errors participated in this adapted alternating treatments single subject design study that explored the functional relation between speech sound intervention that differed by modality of delivery (tablet versus flashcards) and increased speech sound skill in elementary school children with speech sound errors. Flashcards and tablets were both effective speech sound intervention modalities; however, for three of four participants, flashcards were more efficient than tablets. Motivation ratings did not differ across modalities.

Keywords:

Speech Sound Disorder

Articulation

Intervention

Tablet

iPad

The Comparative Efficiency of Speech Sound Interventions that Differ by Modality: Flashcards versus Tablet

Children whose speech sound disorder (SSD) has not resolved by age eight or nine are at greater risk than children who have no history of speech sound disorder or resolved speech sound disorder for low outcomes across a variety of domains. In elementary school, children with persistent speech sound disorder have lower language and literacy skills than children without persistent speech sound disorder (Bishop & Adams, 1990). Recent research suggests that these deficits persist over time. Adolescents with persistent speech sound disorder have higher rates of comorbid language and literacy impairments than those without persistent speech sound disorder (Lewis et al., 2015). In light of the negative long-term consequences of persistent speech sound disorder, research evaluating early speech sound intervention practices is needed.

The Effectiveness and Efficiency of Traditional Speech Sound Intervention

Approaches to the treatment of speech sound disorder are widely variable. A recent comprehensive review reported that 46 distinct approaches were identified in the literature between 1979 and 2009, and only half of these intervention approaches have been studied more than once (Baker & McLeod, 2011). Baker and McLeod concluded that more research is needed to provide evidence on the benefits of different intervention approaches. For the purposes of this paper, we focus on a traditional speech sound intervention approach that has existing empirical evidence of effectiveness and clinical preference (Shriberg & Kwiatkowski, 1982).

Shriberg and Kwiatkowski compared the effectiveness and efficiency of four approaches to speech sound intervention (Shriberg & Kwiatkowski, 1982). Two approaches were primarily drill-based, and two were primarily play-based. The first approach, drill, involved providing instructions, modeling the target stimulus, eliciting a child production, and rewarding the child

for a correct production or providing a subsequent series of teaching events for an incorrect production. The second approach, drill play, was similar to the drill approach, with the addition of a motivational event before presenting the target stimulus. In the third approach, structured play, the clinician prompted the child to produce target sounds only if the child was receptive to attempting the task. Additionally, children were rewarded whether their production was correct or incorrect. Finally, in the play approach, clinicians emphasized a play activity with no mention of the target sound or specific prompting for productions. Clinicians structured the play activity to naturally elicit child productions but never alerted the child's focus to their speech sound.

Results indicated that drill-based approaches to speech sound intervention are more effective and more efficient than play-based approaches. These results align with a meta-analysis of interventions for children with learning disabilities, which indicated that interventions containing a drill component were more effective than those that did not (Swanson & Sachse-Lee, 2000). Additionally, children with mild speech sound needs completed a response-to-intervention speech improvement training in the school system in approximately 17-20 hours (Taps, 2008). In contrast, the average time to criterion in the drill condition in Shriberg and Kwiatkowski was less than 2.5 hours (Shriberg & Kwiatkowski, 1982). Therefore, the drill-based approach utilized by Shriberg and Kwiatkowski is both effective and efficient for improving speech sound production in children when delivered in a traditional modality, that is, pictures presented on flashcards.

The Increase in Tablet Use to Deliver Speech Sound Intervention

The use of tablets and other touchscreen devices in speech-language therapy has increased in recent years. In a survey of over 300 school-based speech-language pathologists (SLPs) (Fernandes, 2011), almost 75% reported owning a tablet or touchscreen device. Of those

respondents, over 80% reported using their device in therapy, overwhelmingly for speech sound therapy and motivation. Approximately 60% of SLPs who reported using this technology in therapy indicated that they purchased the device with their personal funds. This survey data indicates that tablet technology is widely used for speech sound therapy, and the majority of costs are out-of-pocket for SLPs. Therefore, it is vital to determine if utilizing tablets to deliver speech sound therapy is more effective and/or efficient that traditional flashcard speech sound therapy, for which materials are substantially less expensive.

Despite its widespread use, however, tablet technology in speech sound intervention has been evaluated rarely empirically to date. A recent systematic review of computer-based speech sound intervention indicated that computer-based therapy can be effective for some children with speech sound disorders but is not universally effective (Furlong, Erickson, & Morris, 2017). Investigations to date have not evaluated the effectiveness of tablet-based speech sound intervention, even though SLPs are enthusiastic about adopting tablet-based technology approaches for the treatment of speech sound disorders (Gacnik, Starcic, Zaletelj, & Zajc, 2017).

The purpose of this preliminary study was to compare (a) the effectiveness of speech sound intervention using tablets versus flashcards, (b) the efficiency of speech sound intervention using tablets versus flashcards, and (c) child motivation in each condition. Our primary interest was in comparing the conditions of tablet and flashcard presentation of treatment stimuli rather than evaluating the particular evidence-based intervention we selected. Our a priori hypotheses were as follows. First, we anticipated that flashcards and tablets would be equally effective. That is, children would improve to mastery on production of target sounds regardless of condition. Second, we anticipated that tablets would be more efficient than flashcards, and third, that children would be more motivated in the tablet condition. That is,

children would make gains more quickly in the tablet condition because they were more motivated to participate in the therapy.

Method

The research protocol for this study was approved by the Institutional Review Board at the [University].

Participants

The participants were 4 kindergarten students (3 boys) at a local elementary school who had at least two speech sound errors, determined by the screening process described below. All participants were monolingual speakers of English and had normal hearing, determined by parent report. Additionally, participants had nonverbal intelligence and receptive vocabulary within the average range, determined by performance on the Test of Nonverbal Intelligence-4th Edition (TONI-4) (Brown, Sherbenou, & Johnsen, 2010) and the Peabody Picture Vocabulary Test-4th Edition (PPVT-4) (Dunn & Dunn, 2007), respectively. See Table 1 for participant demographic information.

-----INSERT TABLE 1 HERE-----

Procedures

The study consisted of three steps: screening, initial assessment, and the single subject design intervention. First, we screened a classroom of children to identify potential participants. Next, we assessed nonverbal intelligence, language, and early literacy to confirm eligibility and describe participants. Finally, eligible students participated in a single subject, adapted alternating treatment design study that compared the use of tablets and flashcards in speech sound intervention. All research sessions took place in the participants' school.

Screening. A local kindergarten classroom participated in speech sound screening. With the school's permission, a letter was sent home that provided parents the opportunity to opt out of having their child participate in the screening. Of 18 students, 2 parents opted out. Thus, 16 children participated in the screening. The screening was conducted by the first author, an SLP student, and the second author, a certified SLP. To identify speech sound errors, the Goldman Fristoe Test of Articulation-Second Edition (GFTA-2) (Goldman & Fristoe, 2000) was administered to students individually. The goal of the screening was to identify students who had consistent speech sound errors on at least two sounds that differed only by place and/or voicing. Errors could be in initial or final word position, but word position could not differ across targets for each individual participant. The screening identified four children eligible for the intervention study, with the following intervention targets: one child with initial /s/ and /z/, one child with initial /θ/ and /ð/, one child with final /θ/ and /ð/, and one child with /pl/ and /gl/[1]. See Table 2.

-----INSERT TABLE 2 HERE-----

Descriptive assessment. Before beginning intervention, children identified during the screening process participated in a descriptive assessment session to confirm eligibility. As reported above in Table 1, participants completed measures of nonverbal intelligence and receptive vocabulary. All participants scored above a standard score of 90 on each measure.

Single subject intervention. This study employed a single subject, adapted alternating treatment design (AATD) (Sindelar, Rosenberg, & Wilson, 1985) that explored the functional relation between speech sound intervention that differed by modality of delivery (tablet versus flashcards) and increased speech sound skill in elementary school children with speech sound

[1] This child's error was /w/ for /l/ in the blends. He did not have errors in production of the stops in the blend.

errors. The AATD study design compares the rate of acquisition of the targeted behaviors when different intervention methods are used for each condition. Thus, the study design requires two equivalent sets of instructional items for each participant that are taught using different methodologies. In this study, we utilized phonemes that differed minimally as the equivalent instructional targets and modality (flashcard versus tablet) as the different instructional methodology. An effect of intervention modality is present if (a) differences in time to mastery across conditions are observed and (b) these differences are replicated across participants.

Word selection. Target sounds were randomly assigned to intervention conditions for each participant. Intervention in each condition ended when a participant was 100% accurate on the target sound probe assessment for at least 3 consecutive sessions.

After target sounds were identified, words beginning or ending with each target sound were selected using the following process. First, the MacArthur-Bates CDI lexical norms (Jorgensen, Dale, Bleses, & Fenson, 2010) were used to select words that at least 50% of 30-month-olds produce. Next, words were added to the list from the dictionary that were judged to likely be in the lexicon of a kindergarten student and to be easy to picture. Finally, the compiled lists were distributed to speech-language pathologists via a REDCap survey (https://www.project-redcap.org) to rate. The final list of words for each sound was the 20 that were rated most highly for kindergarten students to have in their expressive vocabulary. Of these 20, 10 were randomly assigned to the assessment and 10 different words were assigned to intervention. Five of the 10 assigned to assessment were randomly selected to be included also in the intervention targets. Thus, 10 words were used in assessment and 15 in intervention; 5 words overlapped the two lists. Appendix A contains word lists for each participant.

Intervention material development. After word lists were finalized, intervention materials were created for each participant. First, colored line drawings or color photographs were downloaded for each target word from https://www.iclipart.com. For words assigned to the flashcard condition, pictures were printed on a white background (four per page). Thus, flashcards were approximately ¼ of an 8.5 x 11-inch page. This size allowed for easy "mailing" in a toy mailbox. Flashcards were shuffled before each session to create randomized instructional orders within the flashcard condition. For words assigned the tablet condition, pictures were placed on a Microsoft PowerPoint slide with a white background. A randomization macro was used to create 25 pre-randomized instructional order slideshows in the tablet condition.

Probe assessments. The probe assessment was a progress monitoring measure developed for this study. The probe assessment required children to say aloud the name of a color picture containing the sounds targeted in intervention. This task tapped participants' speech sound of the target sound in the target word position. The examiner presented a colored picture of each stimulus word (e.g., sun) and asked the child to name the picture. If the child did not know the name of the picture, the examiner said, for example, "This is a sun. It makes it light outside. What is it called?"

Participants were assessed three times per week. Probe assessments consisted of 20 test items (10 items each of each target sound) and lasted approximately 10 minutes. Items in the probe assessments were administered in pre-determined randomized orders at each session. Prior to beginning intervention, participants completed four baseline sessions of probe assessment only. Experimental condition probes occurred at the outset of the research session. Following completion of intervention, participants completed four maintenance sessions of probe assessment only.

Experimental condition speech sound intervention. A trained SLP student administered intervention for each participant. Intervention lasted approximately 20 minutes, three days per week. In each session, approximately 10 minutes targeted one sound using flashcards and 10 minutes targeted a different sound using a tablet. Each session contained 30 instructional events as described below, 15 in each condition. Order effects were controlled by alternating the order of instructional conditions (flashcards, tablets) at each intervention session.

The speech sound intervention followed Shriberg and Kwiatkowski's drill model (Shriberg & Kwiatkowski, 1982). In this model, the researcher provided an antecedent instructional event before introducing the training stimulus. The antecedent instructional event consisted of the researcher describing and demonstrating the target sound. Then, the training stimulus was introduced either on a flashcard or on a tablet, depending on the experimental condition. The child then provided the target response by saying the name of the object pictured. Following the child's production, the researcher provided the subsequent instructional event. If the target response contained the correct production of the target sound, the researcher provided praise that included a production of the target sound: "Very good. That's right. You said the [target] sound correctly!" Following a correct production, the researcher provided the subsequent motivational event. The child got to perform a brief fun activity: "mailing" the flashcard in a small red mailbox or swiping to the next photo (i.e., Powerpoint slide) on the tablet. If the target response did not contain a correct production of the target sound, the researcher followed an instructional hierarchy with up to three steps. After an initial incorrect production, the researcher prompted a repetition: "That's not quite right. Our sound is [target]. Try saying that word again." If the second production was also incorrect, the researcher prompted the child to produce just the target sound: "Remember our sound is [target]. Try saying just the [first/last] sound of this

word." If the third production was incorrect, the researcher provided the target sound, exaggerating the duration and prompted the child to repeat it. If after the third instructional sequence, the child still did not produce the target sound correctly, training continued to the next training stimulus without the subsequent motivational event. The researcher "mailed" the flashcard or swiped to the next photo on the tablet.

Motivation survey. Following each condition (flashcard, tablet), children completed a motivation survey. The survey consisted of one question: How much fun did you just have with the [cards/tablet]? The child circled one of five response choices: not at all fun, not very fun, neither fun nor not fun, a little fun, super fun. Picture support was provided for the continuum of motivation (e.g., frowning face emoji to smiling face emoji). The researcher read the question and response choices aloud at each administration (two administrations each intervention condition session).

Procedural fidelity and reliability. Intervention sessions were video recorded to allow for procedural fidelity checks, as well as calculation of reliability of progress monitoring assessment. Procedural fidelity was calculated for 1/3 of intervention sessions. A trained research assistant watched the video recorded session and logged the interventionist's adherence to procedures, including targeting the correct sounds in the correct order and following the intervention protocol step-by-step. Overall procedural fidelity was 95%. The range of procedural fidelity scores across participants was 92 – 97%. Individual sessions ranged from 70 – 100%. All assessment sessions were video recorded to allow double scoring. Interventionists recorded child's scores on-line. The first author separately scored each assessment from video. The scores on each item were compared, and any differences were resolved by consensus. Therefore, final assessment scores represent 100% reliability.

Data Analysis

Analyses were conducted in two stages to compare the effectiveness and efficiency of flashcard-based speech sound therapy relative to technology-based speech sound therapy. First, visual analyses were completed. Results of each probe assessment were graphed to allow for visual examination of data, consistent with single subject design. Second, hierarchical linear modeling (HLM) was employed to quantify the magnitude of change across the study phases and differences between conditions (Davis et al., 2013). A three-level model, including data points nested within therapy sessions within children, was implemented to accommodate the design structure. Phase and condition were added as fixed effect predictors. HLM results were evaluated against findings from visual analyses for consistency.

Results

Figure 1 displays baseline, intervention, and maintenance data for each participant.

-----INSERT FIGURE 1 HERE-----

Comparison of Effectiveness of Speech Sound Intervention by Modality

The first purpose of this study was to compare the effectiveness of speech sound intervention using tablets versus flashcards. As seen in Figure 1, visual analysis of the data for each participant indicated that all participants met mastery criterion for all conditions. Therefore, tablets and flashcards are both effective modalities by which to deliver speech sound intervention. Visual analysis of the data in Figure 1 also indicates that all children maintained gains in speech sound production for each of their targeted sounds, even after intervention had concluded. With the exception of only one data point, children were 100% accurate at production of their target speech sounds on all probes in the maintenance condition

Comparison of Efficiency of Speech Sound Intervention by Modality

The second purpose of this study was to compare the efficiency of speech sound intervention using tablets versus flashcards. As seen in Figure 1, visual analysis of the data indicated that three of the four participants met mastery criterion for the flashcard conditions before the tablet condition. Ashley[2] met criterion for /s/ (tablet) in intervention session 19 and /z/ (flashcards) in intervention session 13. David met criterion for /gl/ (tablet) in intervention session 21 and /pl/ (flashcards) in intervention session 15. Joshua met criterion for /θ/ (tablet) in intervention session 16 and /ð/ (flashcards) in intervention session 7. Walter met criterion for /ð/ (tablet) in intervention session 16 and/θ/ (flashcards) in intervention session 19. Walter was the only participant to meet criterion in the tablet condition before the intervention condition. Therefore, although tablets and flashcards are both effective modalities by which to deliver speech sound intervention, flashcards appear to be a more efficient modality than tablets.

The average time to mastery in the flashcard condition was 13.5 intervention sessions (SD = 5.00; range 7 – 19). For tablets, the average time to mastery was 18.0 sessions (SD = 2.44; range 16 – 21). Cohen's *d* effect size was 1.14, indicating a large effect of intervention condition on sessions to mastery (Cohen, 1988), in favor of flashcards. Each session contained 15 trials in each condition; therefore, participants needed approximately 203 instructional trials for mastery in the flashcard condition, compared to 270 instructional trials in the tablet condition. In terms of time in intervention, sessions were approximately 10 minutes for each condition; therefore, participants needed approximately 135 minutes of intervention for mastery in the flashcard condition, compared to approximately 180 minutes in the tablet condition. Cohen's *d* effect size of the comparison of time to mastery between conditions was 1.14, indicating a large effect.

[2] All names have been changed to protect participant confidentiality.

HLM Results

To estimate the differential effectiveness of the two intervention conditions, predictors were added to the hierarchical linear models in stages (see Table 3). Approximately 13% of the variance in speech sound production values was attributable to unique child characteristics, with an additional 80% of the variability in performance attributable to the child's specific therapy session. These results indicate that there was some variability between children, as would be expected given the children's unique experiences, characteristics, and speech sound skills. Additionally, each child's speech sound production varied strongly between therapy sessions. Each child had days where she or he produced sounds with high accuracy and other days with lower accuracy. These findings are consistent with expectations for a child enrolled in speech sound therapy.

The addition of treatment phase as a predictor revealed that children made significant gains upon introduction of the speech sound intervention (Model One in Table 3). To facilitate interpretation of model coefficients, the active treatment phase was entered as the reference group, with the baseline phase and maintenance phases included as predictors. Results indicate that children demonstrated significantly lower speech sound accuracy in baseline compared to the intervention phase (-5.51, $p < .001$). During the maintenance condition, children produced sounds with significantly greater accuracy than during treatment (2.97, $p < .001$).

Condition was revealed to exhibit both a main effect (Model Two in Table 3) and interaction with phase (Model Three in Table 3). Overall, children produced speech sounds with slightly greater accuracy in the tablet condition compared to the flashcard condition (0.34, $p = .006$). However, examination of condition-by-phase production revealed that this difference was not stable across phases. Children produced speech sounds with greater accuracy in the tablet

condition during the treatment phase (0.62, $p < .001$), but exhibited higher rates of correct speech sound production in the flashcard condition during the maintenance phase (-0.68, $p = .038$).

-----INSERT TABLE 3 HERE-----

Overall, HLM results support those from the visual analyses. Most of the variance in child speech sound production was attributable to child-specific and session-within-child characteristics. Introduction of the speech sound treatment, regardless of the mode of delivery, yielded significant gains in speech sound production. Although there was a significant effect of condition, with the tablets producing a slightly higher effect overall, the difference was negligible when considered with the other factors.

Discussion

To knowledge of the researchers, this is the first study to evaluate the effectiveness and efficiency of tablet-based speech sound intervention (or any kind of speech-language intervention). Because tablet technology in speech sound therapy is widely used but has not been evaluated empirically to date, the purpose of this preliminary study was to compare (a) the effectiveness of speech sound intervention using tablets versus flashcards, (b) the efficiency of speech sound intervention using tablets versus flashcards, and (c) child motivation in each condition. Recall that our a priori hypotheses were as follows. First, we anticipated children would improve to mastery on production of target sounds regardless of condition. This hypothesis was supported by the data. Second, we anticipated that children would be more motivated when using tablets, and consequently, make gains more quickly in the tablet condition. These hypotheses were not confirmed by the data. Our findings indicated that all kindergarten children met mastery for speech sound of target sounds in both conditions. Contrary to our hypotheses, however, most children met criterion in the flashcard condition before they met

criterion in the tablet condition, and there was no difference in motivation ratings between the two conditions.

The first important finding to note was that all participants within the study were able meet mastery criteria for both conditions. SLPs can be confident that either choice of intervention modality can lead to mastery for students with speech sound goals. It should also be noted that our mastery criteria (100% over 3 consecutive sessions) was more conservative than most clinical goals (e.g., 80%). SLPs can also be confident that 100% accuracy is not an unattainable speech sound goal for many clients.

Second, although participants were able to meet mastery criteria in both conditions, three of the four participants met criterion in the flashcard condition before they met criterion in the tablet condition. This difference on average was almost 5 sessions, and the group difference was large. The findings of this study indicate that flashcards may be a more efficient modality for speech sound intervention than tablets. This finding was unexpected. We anticipated that children would make quicker progress in the tablet condition, but the data did not support such a conclusion. Instead, our data support the use of low-tech therapy materials to boost speed of acquisition of instructional targets.

Third, our motivation survey revealed that participants found the two experimental conditions to be equally motivating. Motivational events as simple as “mailing” a flashcard in a toy mailbox or being allowed to swipe to the next picture on a tablet were consistently rated as “super fun” by the participants in this study. There was actually a small effect in favor of mailing the flashcards. Speech sound intervention need not be elaborate, and motivational events need not take time away from intervention (e.g., playing unrelated board games). Our observation was

that more behavior management was needed in the tablet condition; this may explain differences in time to mastery. Future studies should evaluate this hypothesis.

Finally, this study also showed that evidence-based speech sound intervention is effective in a short amount of time. Each week, the children participated in three therapy sessions that lasted approximately 20 minutes, 10 minutes targeting each sound. The average time spent on flashcard intervention to meet mastery criterion was two hours and fifteen minutes, and the average time spent on tablet intervention to meet mastery criterion was three hours. Thus, speech sound errors for some children can be corrected in a fairly short about of time. Stakeholders should continue to consider creative intervention delivery models separate from a traditional IEP, such as response-to-intervention.

As with all studies, the present investigation should be interpreted in light of the following limitation. Because of the single subject design, findings should be applied only to children who are similar to the current participants. Our participants did not present with phonological disorders or with childhood apraxia of speech; therefore, it would be inappropriate to apply these findings to those populations without further research.

Conclusions

The present investigation was the first to our knowledge to evaluate empirically the effectiveness and efficiency of tablet-based intervention. We specifically compared the use of tablets to flashcards to deliver an evidence-based speech sound intervention. Our findings indicated that both modalities were effective in increasing speech sound production skills in kindergarten children; however, flashcards were generally more efficient than tablets. Further, motivation rankings indicated that children were highly motivated in each condition. We conclude that tablets may not be an ideal modality for the delivery of speech-language

interventions for many children. Further research is needed to further understand the efficiency of using tablets in speech-language therapy.

References

Baker, E., & McLeod, S. (2011). Evidence-based practice for children with speech sound disorders: Part 1 narrative review. *Language, Speech, & Hearing Services in Schools, 42*, 102-139. doi:10.1044/0161-1461(2010/09-0075)

Bishop, D., & Adams, C. (1990). A prospective study of the relationship between specific language impairment, phonological disorders, and reading achievement. *Journal of Child Psychology and Psychiatry, 31*, 1027-1050. doi:10.1111/j.1469-7610.1990.tb00844.x

Brown, L., Sherbenou, R., & Johnsen, S. (2010). *Test of Nonverbal Intelligence* (4th ed.). Austin, TX: Pro-Ed.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Davis, D. H., Gagné, P., Fredrick, L. D., Alberto, P. A., Waugh, R. E., & Haardörfer, R. (2013). Augmenting visual analysis in single-case research with hierarchical linear modeling. *Behavior Modification, 37*(1), 62-89. doi: 10.1177/0145445512453734

Dunn, L., & Dunn, D. (2007). *Peabody Picture Vocabulary Test* (4th ed.). San Antonio, TX: Pearson.

Fernandes, B. (2011). iTherapy: The revolution of mobile devices within the field of speech therapy. *Perspectives on School-Based Issues, 12*, 35-40. doi:10.1044/sbi12.2.35

Furlong, L., Erickson, S., & Morris, M. (2017). Computer-based speech therapy for childhood speech sound disorders. *Journal of Communication Disorders, 68*, 50-69. doi:10.1016/j.jcomdis.2017.06.007

Gacnik, M., Starcic, A., Zaletelj, J., & Zajc, M. (2017). User-centred app design for speech sound disorders interventions with tablet computers. *Universal Access in the Information Society, Online First*, 1-12. doi:10.1007/s10209-017-0545-9

Goldman, R., & Fristoe, M. (2000). *Goldman-Fristoe Test of Articulation*. San Antonio, TX: Pearson.

Jorgensen, R., Dale, P., Bleses, D., & Fenson, L. (2010). CLEX: A cross-linguistic lexical norms database. *Journal of Child Language, 37*, 419-428. doi:10.1017/S0305000909009544

Lewis, B., Freebairn, L., Tag, J., Ciesla, A., Iyengar, S., Stein, C., & Taylor, H. (2015). Adolescent outcomes of children with early speech sound disorders with and without language impairment. *American Journal of Speech-Language Pathology, 24*, 150-163. doi:10.1044/2014_AJSLP-14-0075

Shriberg, L., & Kwiatkowski, J. (1982). Phonological disorders II: A conceptual framework for management. *Journal of Speech and Hearing Disorders, 47*, 242-256.

Sindelar, P., Rosenberg, M., & Wilson, R. (1985). An adapted alternating treatments design for instructional research. *Education & Treatment of Children, 8*, 67-76.

Swanson, H., & Sachse-Lee, C. (2000). A meta-analysis of single-subject-design intervention research for students with LD. *Journal of Learning Disabilities, 33*, 114-136.

Taps, J. (2008). RTI services for children with mild speech sound needs: Four years of data. *Perspectives on School-Based Issues, 9*, 104-110. doi:10.1044/sbi9.3.104

Table 1

Description of Participants

Participant	**Age at Study Outset (Years; Months)**	**Nonverbal Intelligence**	**Receptive Vocabulary**
Ashley	5;6	97	110
David	5;10	109	119
Joshua	5;8	101	117
Walter	6;10	93	96

Table 2

Intervention Targets for Each Participant

Participant	Flashcard Condition	Tablet Condition	Differ By
Ashley	/z/	/s/	Voicing
David	/pl/	/gl/	Place/Voicing
Joshua	/ð/*	/θ/*	Voicing
Walter	/θ/*	/ð/*	Voicing

* Final word position was targeted for these participants. Initial word position was targeted for all others.

Table 3

Hierarchical Models of Speech Sound Production

	Model One			**Model Two**			**Model Three**		
Predictors	*Est.*	*CI*	*p*	*Est.*	*CI*	*p*	*Est.*	*CI*	*p*
(Intercept)	6.82	5.48 – 8.16	<.001	6.65	5.31 – 7.99	<.001	6.51	5.16 – 7.86	<.001
Baseline	-5.51	-7.11 – -3.91	<.001	-5.51	-7.11 – -3.91	<.001	-4.88	-6.52 – -3.25	<.001
Maintenance	2.97	1.41 – 4.53	<.001	2.97	1.41 – 4.53	<.001	3.31	1.72 – 4.90	<.001
Condition				0.34	0.10 – 0.58	.006	0.62	0.35 – 0.89	<.001
Condition*Baseline							-1.25	-1.89 – -0.60	<.001
Condition*Maintenance							-0.68	-1.31 – -0.05	.038
Random Effects									
σ^2	0.89			0.84			0.73		
τ_{00}	8.40 $_{\text{Day:ChildID}}$			8.43 $_{\text{Day:ChildID}}$			8.48 $_{\text{Day:ChildID}}$		
	1.42 $_{\text{ChildID}}$			1.42 $_{\text{ChildID}}$			1.42 $_{\text{ChildID}}$		
ICC	0.78 $_{\text{Day:ChildID}}$			0.79 $_{\text{Day:ChildID}}$			0.80 $_{\text{Day:ChildID}}$		
	0.13 $_{\text{ChildID}}$			0.13 $_{\text{ChildID}}$			0.13 $_{\text{ChildID}}$		
Observations	224			224			224		
Marginal R^2 / Conditional R^2	0.343 / 0.945			0.344 / 0.949			0.348 / 0.955		

Appendix A

Word Lists for Each Participant

Ashley				David			
Assessment		Intervention		Assessment		Intervention	
six	zipcode	soda	zeus	globe	planet	glasses	plumber
say	zinc	sit	zack	glance	please	glad	pliers
sandwich	zoo	sock	zap	glow	plus	gloomy	plant
sing	zest	soft	zebra	glider	plaid	glacier	plain
sandbox	zero	sick	zigzag	glovebox	pledge	glide	play
soda	zeus	salt	zucchini	glasses	plumber	glaze	pluto
sit	zack	soup	zip	glad	pliers	glue	plug
sock	zap	sad	xylophone	gloomy	plant	gluegun	plate
soft	zebra	saddle	zee	glacier	plain	gloss	player
sick	zigzag	sink	zipper	glide	play	glob	plow
		sailboat	zone			glare	playdough
		sun	zookeeper			glee	playground
		sister	zoom			glitter	plum
		sofa	ziti			gloves	plastic
		soap	zillion			glass	plane

Joshua				Walter			
Assessment		Intervention		Assessment		Intervention	
south	bathe	faith	sunbathe	wreath	rebathe	path	wreathe
mammoth	smooth	tooth	scythe	mouth	teethe	earth	sheathe
month	scathe	fourth	writhe	moth	bathe	tooth	loathe
truth	seethe	moth	loathe	math	tithe	south	blithe
mouth	soothe	path	teethe	teeth	lathe	cloth	sunbathe
faith	sunbathe	earth	wreathe	path	wreathe	bath	smooth
tooth	scythe	booth	sheathe	earth	sheathe	mammoth	seethe
fourth	writhe	length	clothe	tooth	loathe	truth	swathe
moth	loathe	teeth	unclothe	south	blithe	booth	scathe
path	teethe	bath	lathe	cloth	sunbathe	faith	writhe
		wreath	blithe			fourth	scythe
		both	swathe			both	soothe
		cloth	rebathe			length	unclothe
		north	breathe			month	clothe
		math	tithe			north	breathe

Figure Caption

Figure 1. Visual representation of progress monitoring data.