Annotating digital text with phonemic cues to support decoding in struggling readers

Patrick M. Donnelly¹ , Kevin Larson², Tanya Matskewich², and Jason D. Yeatman, Ph.D.³

¹Institute for Learning & Brain Sciences, Department of Speech & Hearing Sciences, University of Washington

²Microsoft Corporation, Redmond, Washington

³Graduate School of Education, Stanford University; Division of Developmental-Behavioral Pediatrics, Stanford University School of Medicine

An advantage of digital media is the flexibility to personalize the presentation of text to an individual's needs and embed tools that support pedagogy and practice. The goal of this study was to develop a tablet-based reading tool, grounded in principles of phonics-based instruction, and determine whether struggling readers could leverage this technology to improve their decoding skills. The tool presents a small icon below each vowel to represent its sound. Forty struggling child readers were randomly assigned to an intervention or control group to test the efficacy of the phonemic cues. We found that struggling readers could leverage the cues to improve pseudoword decoding: after two-weeks of practice, the intervention group showed greater improvement than controls. This study demonstrates the efficacy of a text annotation, grounded in intervention research, to help children decode novel words. These results highlight the opportunity for educational technologies to support and supplement classroom instruction.

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Correspondence: pdonne@u.washington.edu

Introduction

The discrepancy between the value that society places on literacy and reading achievement levels in American youth (1) is a source of concern both among policy makers and scientists (2, 3). Developmental dyslexia, a learning disability that impacts reading, is widespread, affecting between 5 - 17% of the population (4, 5). Beyond dyslexia, poor literacy rates are a nationwide issue, with 34% of fourth graders performing below the Basic level on national achievement tests (6). Together these results paint a troubling landscape of literacy achievement and illuminate a non-trivial need for expanding access to evidence-based instruction and intervention. For many families of struggling readers, access to high quality, evidence-based interventions outside of school are not only limited, but also represent a significant financial burden (7). Even with a diagnosis, children with reading disabilities struggle to find the support they need in their typical classrooms, necessitating supplemental, after-school programs (8). For this reason, and with the ever-growing landscape of educational technologies, families are turning to digital alternatives. Many apps and technologies are now widely marketed to augment, or even replace, the teacher in delivering intervention for struggling readers. These new tools are advertised as educational, presented as games, and, in general, are fun to use. Although promising, many of these tools ignore the evidence base on effective instruction and inter-

vention techniques and, of the many educational technologies that are available today, very few have studies testing their efficacy (9–11).

In 2012, it was estimated that hundreds of thousands of educational apps had been released on the Apple iOS app store (10). According to a RAND report, children between the ages of three- and five-years old spend, on average, four hours per day interacting with communications technology (i.e., smart phones, tablets, etc.) (12). The Joan Ganz Cooney Center reported, based on a survey of parents, that 35% of children aged two to ten years-old use educational apps at least once per week. Furthermore, federal funds are being devoted to bringing Internet and devices to our nation's schools, providing infrastructure for even greater involvement with digital media in education. However, despite the exciting potential offered by educational technology, parents and educators alike feel overwhelmed by the plethora of options and the lack of guidelines surrounding technologies advertised as educational (10).

Decades of scientific research into the behavioral and neural mechanisms of literacy learning has led to the development and testing of effective intervention programs for struggling readers, and established comprehensive guidelines and best-practices for implementation of an effective curriculum (2, 13–15). Unfortunately, these evidence-based practices (e.g., phonemic awareness, phonics) are largely not being incorporated into the current technological boom. From a sample of 184 apps compiled from online lists of award-winning or highly-rated apps, researchers discovered that although they were entertaining, they lacked scientific backing and “their content, design, production, and distribution are [...] an incomplete response to children's literacy needs, especially for struggling readers” (10). Thus, there is great need for researchers studying literacy development and reading disabilities to work with tech developers on the design of tools that are grounded in the extensive scientific literature on what works for struggling readers, systematically test their effectiveness, and contribute to the development of standards of practice for educational apps targeted at literacy.

This paper outlines a collaboration between the Brain Development & Education Lab at the University of Washington and the Learning Tools team at Microsoft to develop *Sound It Out*, a web-based app that annotates text with phonemic image cues to assist in decoding. This tool is the product of collaborative goals to: (1) create an app informed by the

literature - in this case, explicit phonics instruction (15), (2) focus on an adaptation over an intervention - a supplemental tool that would assist, not replace the teacher, and allow children to bring skills from the classroom to at-home practice with reading (16–18), (3) design a fun and whimsical interface that children would want to use (19, 20), and (4) enable children to confront their challenges and build the skills to decode more complex words. Our focus on explicit phonics instruction is based on decades of research detailing its importance in literacy education (19, 21–25), and the unique role that technology affords to provide limitless exposure and practice inside and outside the classroom. The tool was designed through collaboration between the researchers at the University of Washington (P.M.D. and J.D.Y) and Microsoft (K.L., T.M.), and then tested (independently) in a laboratory study using a pre-registered randomized control trial design to determine whether a conceptually simple digital tool can lead to improved word reading outcomes for struggling readers.

Methods

A. Pre-registration. The methods, including study design, hypotheses, and analysis plan, were pre-registered using the Open Science Framework (OSF) open-access, pre-registration pipeline. We obtained initial reviews and feedback on this pre-registration from an independent OSF reviewer, revised and re-submitted our methodology, and then adhered to this pre-registered plan throughout the duration of the study. Documentation is available at <https://osf.io/q8tpz>.

B. Participants. Forty children between the ages of 8 and 12 were recruited from the University of Washington Reading & Dyslexia Research Program database, an online repository of families interested in dyslexia research in the Puget Sound region. The participants (19 females; 21 males) were classified as struggling readers based on a battery of behavioral measurements administered within one year of participation in the present study. Here, we use the term “struggling reader” rather than “dyslexia” because there is substantial variability in diagnostic criteria for dyslexia and our goal was to design a tool that would support literacy development for anyone that was struggling, regardless of a dyslexia diagnosis. To be considered a struggling reader, participants needed to have reading skills that were more than one standard deviation (SD) below the mean on either the Woodcock-Johnson IV Tests of Achievement Basic Reading Skills composite (WJ BRS) or the Test of Word Reading Efficiency - 2 Index (TOWRE Index), and scores above 1 SD below the mean on the Wechsler Abbreviated Scale of Intelligence Full Scale-2 composite (WASI FS-2). Participants were previously screened for potential speech/language/hearing disorders, neurological impairments, and psychiatric disorders and had none. ADHD was not a disqualifying factor as there is a high co-occurrence with reading disability (26), 2006). Demographic information on the sample can be found in table 1.

The parents of all participants in the study provided written and informed consent under a protocol that was approved

by the UW Institutional Review Board and all procedures, including recruitment, child assent, and testing, were carried out under the stipulations of the UW Human Subjects Division.

C. App Design. *Sound It Out* is a web-based application (web app) that annotates text passages with visual phonemic cues to assist decoding. When a passage is viewed using the web app, the vowels appear in blue font with the image cues (located just underneath) indicating the associated phoneme. Each image cue is a highly recognizable symbol whose name contains the target vowel sound for the vowel above. For example, in the word “cow”, “o” would appear in blue, with the symbol of a house below. The house cues the child that the “o” in “cow” makes the same sound as the “ou” in “house”: /aʊ/. Fig. 1A shows three sentences taken from a grade level passage and annotated with *Sound It Out*. To aid in symbol recognition and retention, the app also integrates a voice cue; when a child presses the phonemic cue symbol, a voice narrates the symbol name followed by an isolated presentation of the target vowel sound. For example, in the “cow” example, when a child presses the image of the house, below “o”, a voice will say, “house, /aʊ/”.

The goal of this app is for the cues to provide helpful hints that aid in decoding and provide children the support they need to attempt to decode difficult words and, eventually, learn the highly inconsistent grapheme-phoneme correspondences of vowels in English. Instead of simply reading challenging words, as is typical in a speech-to-text tool (27, 28), *Sound It Out* focuses on a particularly difficult task for struggling readers: vowel decoding. Because vowels in English represent the majority of ‘mutually interfering discriminations’ - or multiple sound associations - that young readers must master (29), learning the rules for vowels represents a significant portion of phonics curricula (3, 13, 30). With the understanding that vowels may not be the only challenge for the reader, *Sound It Out* was designed to provide a tool that scaffolds learning and empowers struggling readers to read more complex passages independently. *Sound It Out* was designed as a feature that can be turned on or off when a child is reading. In this study, both intervention and control participants were given a tablet and taught how to use it for reading. The primary manipulation was whether the *Sound It Out* feature was turned on. Beyond this manipulation, the text in the table-based reader was identical.

D. Procedure.

D.1. Study Design. In a randomized pre-post design, all participants completed an initial, baseline session that collected all outcome measures using a normal text condition presented on a Kindle fire tablet without the *Sound It Out* cue (see **Outcome Measures**). Then, participants were randomized to a control or intervention condition. Control participants completed a brief training in use of the tablet then a two-week, at-home practice program without the *Sound It Out* tool. Intervention participants completed an extended training period in use of both the tablet and the *Sound It Out* cue prior to

Characteristic	Intervention (N=20)	Control (N=20)
Age (years)	10.34 (1.3)	9.79 (1.1)
Female (proportion)	0.5	0.45
WJ Basic Reading Skills Composite	78.5 (12.92)	81.15 (8.43)
TOWRE-2 TWRE Index Composite	70.25 (7.48)	70.65 (7.10)
WASI Full-Scale 2 Composite	97.6 (8.75)	100.15 (17.20)
CTOPP Phonological Awareness Composite	87.2 (9.7)	83.4 (11.94)
CTOPP Rapid Naming Composite	79.05 (8.57)	77.75 (6.7)

Table 1. Demographic information for participants in the Intervention and Control groups. See Methods for descriptions of the individual characteristics. For each characteristic the mean is provided with the standard deviation within parentheses.

A

"Thank you," said Master Fox sweetly,
as he walked off. "Though it is
cracked, you have a voice sure
enough. But where are your wits?"

B

IPA	Cue Word	Cue Symbol	IPA	Cue Word	Cue Symbol	IPA	Cue Word	Cue Symbol	IPA	Cue Word	Cue Symbol
/ɑ/	Heart		/ɜ/	Earth		/aʊ/	House		/oʊ/	Bone
/æ/	Ant		/eɪ/	Grape		/əl/	Wolf		/ɔɪ/	Coin
/ʌ/	Sun		/ɪ/	Pig		/aɪ/	Eye		/ʊ/	Book
/ɔ/	Dog		/i/	Keys		/ɛ/	Bed		/u/	Moon

Fig. 1. *Sound It Out* example text. The vowels in this excerpt from "The Fox and the Crow" fable appear blue with phonemic image cues provided below. The name of the symbols cues the reader to the sound of the target vowel.

an identical at-home practice program with the tool turned on. After two weeks, all participants returned for a post-intervention visit where the intervention participants were tested with the cue, while control participants experienced the normal text condition.

D.2. Training program. For the intervention group, each child was first oriented to the presence of the cue in an example passage. The researcher would show a passage with the cue and say the following: "Now we are going to use a cool tool that we made to help you read the tricky words. Underneath each word we have symbols that help you figure out the sound that the blue letters make." The researcher would

walk through a word and demonstrate how the cues could be used to help decode words. Then the researcher explained when to use the cues: "When you come a word you don't know, just look at the symbols and that should help you figure out the sounds that the blue letters make." The child was then instructed to read through the passage. When they came to tricky words the researcher alternated between clicking on the symbols and naming the symbols to help sound out the words that cause difficulty. If the child read through the first example passage with ease, a more challenging passage was added to ensure that the child had demonstrated efficient and correct usage. Then, with the use of flashcards, the researcher reviewed each symbol explicitly with the child.

For the control group, participants were introduced to the tablet and instructed on how to navigate to the various passages for at home practice. They were not shown the phonemic cues, but otherwise followed an identical procedure.

D.3. At-home practice. After training with the application, and when the baseline testing session was completed, participants were provided tablets to take home for reading practice. Participants were asked to read at least one story per day over the course of two weeks using the app (at home). For the intervention group the *Sound It Out* feature was enabled so that phonemic cues showed up in the passages. For the control group text was rendered in the same font but without the cues. Tablets were pre-loaded with 36 first, second, and third grade supplementary passages for children to read with or without their parents. To encourage meaningful practice, parents were provided with a brief introduction to the app prior to taking home the tablet and were given instructions to allow the child to work through difficult words using the image cues prior to providing any additional guidance. For those that adhered to these instructions, and assuming each passage would take approximately ten minutes to complete, each child experienced at least 100 minutes of exposure over the two-week practice period. Adherence to the practice schedule was measured via short, three-question comprehension quizzes completed after reading a story (through a web interface). A participant was only credited for a practice passage if they received a comprehension score of at least two.

Supplementary passages for at-home reading were from ReadWorks.org, an online library of grade-level passages (used with permission of ReadWorks). Passages were phonetically coded manually by the research team based on the most common pronunciation in the Pacific Northwest dialect of English. The code was verified by both P.M.D. & K.L., with inconsistencies discussed and decided via consensus. All passages were displayed on an Amazon Kindle Fire 8 tablet at a set font size and resolution. Comprehension questions, to gauge practice adherence, were created by a trained, certified teacher at a local school that specializes in working with children with developmental dyslexia and were grade-level matched to the individual passages. Passages and comprehension questions can be found in the supplementary material (see **Supplement**).

E. Outcome Measures. Measures of reading performance were collected at baseline and after the two-week period of practice. Real and pseudo word decoding accuracy was measured by having participants read lists of words that were loaded into the web app. Four unique lists of 30 real and pseudo words were created with two lists being delivered at each visit. All lists were developed using the orthographic wordform database MCWord (31). Real word lists consisted of the most frequent words in the English language with five instances each of three-letter to eight-letter words. Pseudo word lists consisted of the most frequent bigrams in English with an identical progression from three-letter to eight-letter pseudo words. All lists were unique and were rated for consistent difficulty using timed reading in ten typically reading

adults. Lists were administered in a counterbalanced order for participants in each group. Lists were phonetically coded manually by the first author based on the most common pronunciation in the Pacific Northwest dialect of English. Accuracy in pronunciation was not limited to the code used for the phonemic cues but extended to acceptable pronunciations in English. Accuracy of real and pseudo word decoding was our primary outcome measure (number of words read correctly on each list akin to the Woodcock Johnson Word ID and Word Attack).

Passage reading rate and accuracy was measured by having participants read grade level passages that were loaded into the web app. All testing passages used were from the Dynamic Indicators of Basic Early Literacy Skills (DIBELS) 6th Edition library, used with permission of the University of Oregon Center on Teaching & Learning. These passages are commonly used as benchmark assessments in schools and have been extensively used in reading research. Only passages rated at second, third, and fourth grade were used. For each testing session, every passage was presented by a research assistant in the Brain Development & Education Lab and audio recorded for accurate scoring and coding. Instead of constraining the oral reading to the one-minute limit of the DIBELS protocol, all passages were read to completion twice in a repeated reading design. Each passage reading yielded four measures: accuracy (number of words pronounced correctly) on the first and second read; and rate of reading (number of accurate words per minute) on the first and second read. To test the influence of *Sound It Out* on connected text reading, analyses focused on the word-reading accuracy of the first read and the word-reading rate of the second read. Second reading rate was used to control for the added time that might be associated with using the phonemic cues to sound out difficult words on the first read. Testing passages were coded and rated in the same manner as the at-home practice passages.

F. Statistics. Due to the presence of missing data, data were analyzed with linear mixed effects (LME) models, as specified in our pre-registration. For each outcome measure we fit an LME model with fixed effects of: (1) time (pre-intervention / post-intervention as a categorical variable); (2) group (intervention / control groups as a categorical variable); (3) the group by time interaction. The models included independent random effects of time and participant, to account for individual variation in baselines and growth. Practice data were used to ensure that all participants engaged with the tool at home, and were also used in correlational analyses to examine the impact of at-home exposure on improvement. Analyses were carried out using the NumPy and SciPy libraries of Python and the MATLAB Statistics Toolbox (2019a) (32). All data and analysis code associated with this manuscript are publicly accessible at the following link: https://github.com/patdonnelly/Donnelly_2019_SSR

Results

A. Phonemic cues improve decoding accuracy for real and pseudo words. For our primary outcome measure (as specified in our pre-registration [link]), children were assessed on their ability to decode lists of increasingly more complex real and pseudo words prior to, and immediately following, the two week intervention period. For this measure of decoding accuracy, words were displayed in a list (Fig. 2A). Fig. 2B/C depicts difference scores between the first and second visits (positive bar heights indicate that more words were read correctly on visit 2).

For real-word decoding accuracy there was a significant increase in the intervention group ($\beta=1.875$, $t(78)=3.77$, $p=0.0003$) and a small but non-significant increase in the control group ($\beta=0.575$, $t(78)=1.13$, $p=0.262$). However, the group by time interaction was not significant ($\beta=1.267$, $t(151)=1.215$, $p=0.138$) indicating that the growth in the intervention group was not statistically different from the control group. For pseudo-word decoding accuracy there was a significant increase in the intervention group ($\beta=2.075$, $t(78)=2.23$, $p=0.028$) and a small but non-significant decrease in the control group ($\beta=-1.1$, $t(78)=-1.18$, $p=0.242$). The group by time interaction was significant ($\beta=3.179$, $t(151)=2.352$, $p=0.02$) with the intervention group showing significantly greater improvement than the control group (a threshold of 0.025 was defined in the preregistered report to adjust for multiple comparisons).

To determine the influence of practice on individual outcomes, we examined the correlation between at-home practice and individual growth. All participants completed at-home practice (intervention Mean = 13 stories, SD = 6; control Mean = 12, SD = 6), but the correlation between amount of practice and growth was not significant for the intervention group (real words $r = -0.14$, $p = 0.55$; pseudo words $r = 0.23$, $p = 0.35$) or the control group (real words $r = 0.01$, $p = 0.97$; pseudo word $r = -0.37$, $p = 0.10$).

These findings show that without the constraints of time during testing, there was a beneficial effect of access to the phonemic cue for single word decoding. This benefit was particularly pronounced in the case of pseudoword decoding where children were asked to pronounce novel words in isolation. Although the effect size was moderate (Cohen's $d = 0.74$ for pseudoword decoding), these results suggest that children, with practice, can incorporate a novel cue to scaffold independent decoding.

B. Phonemic cues for connected text reading. To determine whether the phonemic cue confers a benefit for reading connected text, we assessed word reading accuracy and rate on grade-level passages before and after intervention. Fig. 3 depicts the difference scores for the control and intervention participants in terms of (a) reading accuracy: number of words read correctly in the passage on the first read; and (b) reading rate: number of correct words per minute in the second read. Bar heights represent the difference in performance between the two visits.

For word reading accuracy there was a non significant in-

crease in the intervention group ($\beta=0.016$, $t(130) = 1.77$, $p = 0.078$) and a non-significant increase in the control group ($\beta=0.005$, $t(142) = 1.07$, $p=0.286$) but the group by time interaction was not significant ($\beta=0.015$, $t(61)=0.59$, $p=0.559$). For word reading rate there was a non-significant increase in both the intervention ($\beta=0.04$, $t(126)=1.67$, $p=0.098$) and control groups ($\beta=0.027$, $t(142)=1.96$, $p=0.054$) and a non-significant group by time interaction ($\beta=-0.072$, $t(60)=-0.843$, $p=0.403$).

Discussion

Using a small-scale randomized control trial design, we tested the hypothesis that struggling readers could leverage a phonemic image cue placed below the vowels in digitally presented text to improve reading accuracy for isolated words and connected text. Data collected after a two-week period of unsupervised (but digitally monitored) practice demonstrated that struggling readers' decoding skills improved: compared to the control group, the intervention group showed a significantly larger improvement in decoding accuracy specifically for pseudo-words. In connected text reading, growth was observed for all participants but without a significant difference between groups. These data suggest that, although the participants were able to effectively use the cues in isolated situations, the tool did not become sufficiently automatic to produce gains in passage reading fluency.

Decades of dyslexia research has been devoted to developing and systematically testing interventions aimed at struggling readers. In the digital age, devices provide ever-expanding access to a plethora of educational apps and resources advertised as educational. Many families seek out these resources to supplement their child's education. Unfortunately, most of this educational technology lacks scientific backing (33). A goal of this project was to embed a core feature of evidence-based practice in literacy instruction into a digital tool to scaffold learning to read. Inspired by the key tenants of phonics instruction (e.g., explicit and clear instruction in letter-sound correspondence, repeated exposure, and systematic practice), the phonemic cue was designed to provide struggling readers a hint to aid the decoding of novel words. We focused on vowels because the highly inconsistent grapheme-phoneme mapping is a major hurdle for struggling readers. In a landscape of digital tools that provide instant corrections at the whole word level, the phonemic cue annotation in this study is one of a only a few learning aids that provides an element of instruction (at the phoneme level) to support generalizable skill (27, 34, 35). Instead of being given the answer at the first sign of struggle, the child can utilize the phonemic cue to learn part of the word, yet still needs to exercise the building blocks of literacy to get the answer.

In a similar vein to this work, researchers in the UK developed *Trainertext*, a scaffolding program that provides whimsical, visual mnemonics for scaffolding letter-sound correspondence. Instead of focusing on vowels, *Trainertext* provides a visual cue above every phoneme in connected text that is associated with short rhyme. For example, above the word "gas", *Trainertext* has images related to the phrases "Goat in

Fig. 2. Untimed decoding performance on real and pseudo words. (A) Example stimuli from the real-word (left) and the pseudo-word (right) lists with *Sound It Out* phonemic cues below the highlighted vowels. (B) Difference scores (number of words read correctly) from the first and second visits for both the control and intervention groups on real word lists. (C) Difference scores from the first and second visits for both the control and intervention groups on pseudo word lists. Bar heights represent the additional words read on the second visit. Error bars reflect ± 1 SEM.

Fig. 3. Accuracy and rate for connected text reading. Bar graphs depict difference scores from the first and second visits for both the control and intervention groups for word reading accuracy (A) and rate (B). Bar heights represent the additional number of words read correctly and additional accurate words per minute on the second visit. Error bars reflect ± 1 SEM.

a Boat”, “The Ant in Pink Pants”, and “The Snake with a Shake” to represent the grapheme-phoneme correspondence of each letter. A randomized control trial with individualized instruction and 10 months of exposure demonstrated significant improvements (effect size = 0.80) with the largest effects seen for decoding and phonological awareness (34). This work demonstrated how phonics-based text annotation

could be leveraged by struggling readers to bootstrap their decoding skills. The present study built on this work by (a) employing a simplified symbol set focused on vowel sounds, with the hope of building a tool that would be quicker to learn and less cognitively demanding and (b) could be used immediately without requiring months of a resource-intensive intervention program. Taken together, these two studies em-

phasize that text annotation is a promising approach either in combination with an in-person intervention (as in (34)), or as a tool to support at-home practice (as in the present study).

As was the case with *Trainertext*, *Sound It Out* requires children to learn a new, albeit intuitively designed, symbol system and practice sufficiently for the associations to become automatic. The symbols chosen were optimized for recognizability, but the challenge remains in teaching the child to associate a portion of the symbol name with a discrete sound segment in an often-unrelated word. Moreover, the sound-symbol association must be fast enough to not impede short term memory with increased cognitive load (36–38). These two dimensions, effective use and automaticity, are captured by the two areas of measurement: the untimed words lists and the connected text reading.

The finding of improved decoding performance, specifically for pseudowords, indicates that without temporal constraints or the cognitive demands of connected text reading, children can use the phonemic cue to improve decoding performance. This suggests that the training period was enough and the tool sufficiently intuitive to have an impact. As the limited effects in passage reading accuracy and rate reveal, however, the tool proved incapable of extension when those constraints were re-introduced. Either due to the limited practice period, limited supervised practice, or conflict with existing strategies children use when approaching challenging words, children did not similarly benefit from the phonemic cues in connected text. We had anticipated that the cue would require limited exposure, but our results are in stark contrast with previous studies that have instituted a more comprehensive, extended training program and observed significant benefit to fluent reading (34, 39). Thus, although the training and practice periods were enough to encourage effective use, it was not enough to ensure automatic and fluent use in a natural setting.

In fact, the limited effects in accuracy and rate performance suggest that either the cue did not adversely impact reading performance or that it was underutilized given the increased cognitive demands of real-time reading. Many participants in the study were receiving supplemental instruction regularly and have learned strategies for approaching new words. As a novel strategy, the phonemic cue may have been overridden when children were asked to read continuously and for comprehension in our sample. In line with the corpus of research on strategy instruction for literacy (37, 40–42), although the children in our sample demonstrated competency in the use of the cue in isolated, single-word decoding, strategy adoption would require more sustained exposure.

A strength of educational technologies for literacy is their ability to empower parents, teachers and other advocates to support and supplement their child's learning outside the classroom (34, 43–46). *Sound it Out*, is unique in that it provides a tool that gives parents a strategy for reinforcing phonics principles with their child. Many parents, when confronted with the stress and challenge of raising a child who struggles with learning to read, are told to read more to their child, but not given the knowledge base needed to provide

meaningful support (47). Post-study feedback from parents in the study were overwhelmingly positive, with a majority of parents noting interest in using the tool into the future (see **Supplement**). Relatedly, a study by Ronimus and colleagues demonstrated increased efficacy of *GraphoGame*, a digital literacy program, for reading performance when children engaged with the tool with parental involvement (46). Thus, with parental support and potential alignment with the teacher and in-school curriculum (33, 48–53), *Sound It Out* represents a promising venture bridging research and practice.

In aggregate, these findings represent proof-of-concept for this novel approach to assisting struggling readers by merging the extensive evidence base on effective literacy instruction and the affordances that technology lends to the educational arena. Not only did it prove effective in improving decoding performance with very limited practice, but it also proved to be non-detrimental to passage reading, meaning that it was not too cognitively demanding. Future research should focus on optimizing training and practice to produce gains that will extend beyond isolated single word decoding and lead to more confident, fluent readers.

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