Colouring the Path from Instruction to Practice: Perspectives on Software for Struggling Readers

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ABSTRACT

Mainstream paper and pencil interventions for Anglophone students with dyslexia emphasize a strategy of analyzing syllables to compensate for irregularities in English letter-sound correspondences. Classroom interventions have developed effective scaffolds for supporting students in analyzing syllables in instructional contexts. However, students typically fail to transfer knowledge to practice contexts (i.e, reading without a tutor). Software has proven to be an effective medium for helping dyslexic students practice basic literacy skills (phoneme awareness and letter knowledge). However, at present, there are no systems specifically designed to support dyslexic students in practicing syllable analysis. Correspondingly, there is a lack of information about which design features would best support dyslexic students in transferring syllable analysis skills from instructional (classroom) to practice (software) contexts. In an attempt to address this gap, we propose two guidelines for software supports of syllable-analysis in dyslexia: 1. Design software that serves as a dual medium for instruction and practice 2. Design scaffolds that serve as dual catalysts for learning and transfer. We realize our guidelines in a prototype software system for syllable analysis that uses colour-coding to direct attention to information during learning and to retrieve learned information during practice.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation]:** User Interfaces- *input devices and strategies.*

General Terms

Design, Human Factors, Theory.

Keywords

Dyslexia, interface strategies, theory, colour coding

1. INTRODUCTION

Students with dyslexia struggle to learn the correspondences between the letters and sounds of their language [10]. Learning English poses especial challenges because letters often correspond to multiple sounds. For example, consider the different sounds of "a" in the words: "cat","star" and "fade" [17]. In English, decoding a single letter often requires attention to a wider orthographic context: the letters that surround it [17]. One important context is the syllable [4,6]. Certain syllables are "stable": they occur in many words and always sound the same (e.g., "tion"). Others fall into types (e.g., "closed syllable"). Types are specific arrangements of consonants and vowels (e.g., a closed syllable is consonant-vowel-consonant). Readers who recognize types can exploit the fact that each type predicts a specific vowel sound (e.g., the vowels in closed syllables sound short) [4,5]. Fluent readers use memorized stable syllables and types to decode unfamiliar words [2,6,17]; training to recognize stable syllables and types can improve decoding [2,6]. These observations have motivated educators to incorporate syllable-based decoding into interventions for struggling readers [2,6].

There are many approaches to supporting students with dyslexia overcome the challenge of syllable analysis. The challenge is shifting attention between different orthographic units, knowledge and skills [2,6]. For example, consider the steps involved in decoding the word "cradle": 1. recognize the stable syllable "dle" and "segment it" away from the word. 2. Recognize "cr" as a consonant blend, and group it with the vowel. 3. re-code the letter-units "cr" and "a" as the open (consonant-vowel, or CV) syllable type. Finally, remember that CV vowels sound long. Paper and pencil approaches have developed various scaffolds to help students succeed in these steps. All scaffolds attempt to direct students' visual attention to the relevant orthographic units or sounds, for example, drawing boxes around syllables and annotating sounds [2,4,6,8]. These scaffolds help students demonstrate syllable analysis in instructional contexts when tutors are available. However, they do not support students in transferring knowledge [2].

Transfer refers to the students' successful application of a decoding strategy to an uninstructed word. For example, a student who learns to recognize "dle" with the word "cradle" is said to have transferred that knowledge when they recognize the unit "dle" in the analogue, "cuddle". Many students do not generalize syllable analysis to words they encounter alone [2]. Adults can cue students to apply the appropriate strategy, but this limits practice to contexts where adults are available.

A key role for software in supporting students with dyslexia is enabling decoding-practice when adults are unavailable [11]. Software can simulate the scaffolding that tutors provide. For example, a software implementation of syllable analysis could cue students to recognize stable units by rendering a box around them. Various software supports for students with dyslexia exist.

IDC '15, June 21 - 25, 2015, Medford, MA, USA
© 2015 ACM. ISBN 978-1-4503-3590-4/15/06…$15.00
DOI: http://dx.doi.org/10.1145/2771839.2771909

Adding them to classroom instruction improves some literacy skills [11]. So far, however, software supports have focused on basic skills, such as phoneme awareness or letter recognition, versus complex ones like decoding multi-syllable words. Another issue is the disconnect between software and classrooms. Software uses various multimedia feedback that tutors cannot. The difference in the sensory environments of classroom-based learning and software-based practice could prevent students from transferring knowledge between instruction and practice. Conversely, equating the environments for instruction and practice could enhance transfer.

The multimedia feedback that software provides might have special benefits to students with dyslexia [11]. Therefore, an ideal solution might be software that supports instruction as well as practice. In this paper, we present a prototype that illustrates two extensions of software supports for students with dyslexia: 1. Providing an integrated medium for tutor-driven instruction and student-driven practice 2. Leveraging the software medium through the research and development of a unique set of visual scaffolds that are deployed during instruction and practice as attentional and mnemonic supports.

2. THEORETICAL BACKGROUND

We adopted a theory-driven approach to design that involved a review of basic literature on the attentional challenges of students with dyslexia, the attentional demands of syllable analysis, and the attentional scaffolds that might help. We balanced our theoretical analysis with a review of classroom approaches. Our analysis helped us identify ways that software could uniquely enhance paper and pencil approaches. Our review identified two core attentional challenges to syllable analysis. The goal of mitigating these challenges drove the design of our scaffolds. The challenges are: focusing and associating. We describe them below:

Focusing: students with dyslexia present impairments in the visual and parietal systems that focus attention to visual contour [14]. They also have difficulty suppressing irrelevant information and switching attention between visual units [13]. These challenges are relevant to syllable analysis. Difficulties focusing to visual contours could prevent students from recognizing stable units. Syllable-based decoding requires the sequential coordination of several pieces of information. Difficulty suppressing irrelevant information (e.g., blends when seeking stable syllables) and switching attention between visual units (e.g. stable units to blends) could cause interference between different kinds of orthographic information [3].

Associating: students with dyslexia have difficulty associating segments of speech (e.g., phonemes, or larger units like syllables) to segments of text (letters, "ble"). This challenge is curious because students with dyslexia can associate other kinds of auditory and visual stimuli, such as musical notes [4]. Accordingly, several theorists think that the difficulty concerns the poor discriminability of English letters, which in turns makes it harder to discriminate English sounds [3]. Other theorists draw attention to the arbitrariness of the relation between English letters and speech sounds [4]. This challenge is relevant to syllable-analysis because it impedes the memorization of stable-syllable and syllable type sounds.

If software is to serve as a medium for instruction and for practice, it must appear valuable to the tutors who would use it. Therefore, having identified the main impediments to syllable analysis, we questioned what unique scaffolds could software provide to support students focusing on and associating letter-units to sounds?

Part of our approach involved assessing how mainstream paper and pencil approaches support students. Mainstream paper and pencil approaches use visual elements such as boxing or annotating the sounds of letters to help students focus and associate letters to sounds. However, the finding that students with dyslexia present disturbances in serial visual attention suggests that small annotations are suboptimal. Likewise, although large boxes are visually salient, they communicate little additional information, such as the unit's sound.

One intriguing class of approaches uses colour. Berninger [3] and Hines [9] colour-highlighted letter-units to help students identify them in sentences or words. The colours seemed to help students focus attention to the target letter-units and bind them to their sounds. Our literature review provided independent reason for assuming that colour-highlighting helped. Students with dyslexia exhibit typical parallel search for coloured targets [14]. Parallel search for coloured targets implies rapid recognition of and focusing to colour targets [14]. By the same token, when a target is uniquely coloured students might have an easier time ignoring uncoloued distracters ("irrelevant information"). Other approaches used colour to help students associate letters to sounds. Gillingham and Stillman colour-coded letters as consonants (white) or vowels (red) to help students categorize letters as consonants or vowels [8]. Caleb Gattegno mapped speech-sounds to colours and immersed students in words that were coloured by sound [7]. Both measures seemed to help students associate letters to sound. Again, we uncovered independent reason to assume that colour helped. Humans may naturally associate certain colours to speech sounds [16]; humans readily associate text to colours [12]. If associations are transitive [15], then colouring letters 'by sound' could associate the letters to sound. Transitive colour-sound and colour-letter associations could overcome the arbitrariness of letter-sound associations.

Colour could therefore scaffold students' acquisition of syllable analysis. Furthermore, software can leverage colour in ways that paper and pencil cannot. One capacity of colour that paper and pencil approaches have not exploited is that of colour changes to re-focus attention [5,12]. The potential benefits in syllable-analysis are clear. Each step of syllable analysis requires a shift in attention to different orthographic units. Changing the colour of the unit at the time it should be attended is an exogenous cue that could compensate for students' impairments in endogenous attention. Software can more easily update the colours of digital letters than tutors can update the colours of paper-and pencil letters. Finally, colour-codes can cue information with which they are associated [5], and learners readily integrate different sources of information that are coloured the same [12]. Colour could facilitate transfer by a) becoming associated with instructional knowledge b) cueing memories of instructional knowledge c) helping learners integrate various instances ("cradle", "cuddle") of the same concept ("dle").

3. PHONOBLOCKS: DESIGN SOLUTION

PhonoBlocks is a new variation of an ongoing work-in-progress. We described our first variation in an earlier paper [1]. PhonoBlocks was designed with reference to our expanded literature review and iterated focus groups with specialized tutors of children with dyslexia. This paper and section describes PhonoBlocks as a "proof" of an alternate design concept: an integrated platform for instruction and practice that uses colour-codes to scaffold and cue knowledge for syllable-analysis. PhonoBlocks involves custom-built software that was written in c# and implemented in the Unity game engine. It runs on a Sony VIAO multi-touch laptop. Upon beginning the application, the user can choose either tutor-driven (instruction) or student-driven (practice mode). Student-mode features an additional menu enabling tutors to customize the distribution of practice words involving stable syllables, blends, and the different syllable types.

3.1 Colour-Codes

PhonoBlocks' core feature is the set of colour codes by which it facilitates focusing, association and transfer. We designed each colour-code to support one of three steps in syllable-analysis: identifying stable units, identifying blends and identifying syllable types and their relation to vowel sounds. PhonoBlocks applies the active code to the onscreen word. To focus attention to relevant information, each scheme colour-highlights just one kind of letter-unit; all other letters are white.

Figure 1. Each colour-scheme, applied to the word "cradle". From the left: large units, blends, and vowel sounds.

3.1.1 *Identifying Stable Units (SU)*

We designed this scheme to help students learn stable syllables and their positions in words. Stable syllables always appear at the start (e.g., prefixes, such as "un") or end (e.g., suffixes, such as "ish", or "ble") of words. Like Hines [9] and Berninger [3], we highlighted stable units by colouring their letters uniformly. We extended their approaches by choosing colours for front and end syllables that suggested their positions: green, for "go", was assigned to "starting" units; red, for "stop", was assigned to end units.

3.1.2 *Identifying Blends (BL)*

Like stable units, blends are groups of letters with positional restrictions. There are front blends, end blends, and those which can occupy either position. For consistency with the large units scheme, letters of blended units were coloured uniformly. Front blends were green; end blends were red. Blends without restrictions were yellow.

3.1.3 *Learning Syllable Types and Vowel Sound Associations (ST)*

We designed this scheme to help students identify syllable types and learn their correspondence to vowel sounds. The operation that this scheme supports is dividing words into syllables. Contemporary approaches instruct students to identify syllables by looking for vowels [1]: each syllable has exactly one vowel. To focus students' attention to vowels, only vowels were coloured. (Consonants were white). One exception was "r". "r" plays a special role in the r-controlled syllable type. To help students recognize r-controlled syllables, we coloured "r" blue.

Another goal was using colour to leverage students' background knowledge to help them associate letter-patterns to sounds. Auditory vowels are energy peaks [2,6]. Humans readily identify vowels in continuous speech [6]. To represent the salience of acoustic vowels, vowels were warm colours. Syllable types predict 3 kinds of vowels: short, long, and r-controlled. In choosing colours for short and long vowels we leveraged the fact that our target grades' (3-5) science curricula include the electromagnetic spectrum. Their knowledge that red and yellow corresponds to longer and shorter wavelengths was expected to help them associate red to long vowels and yellow to short ones. R-controlled vowels only occur in r-controlled syllables. To explicate the influence of "r", we coloured r-controlled syllables magenta: a warmish colour, but affected by blue. The rationale behind choosing colours that associated easily to sounds was enabling students to virtually "see" the sounds that syllables contain. I.e., for example, seeing that the vowel in CVC is yellow would be like "seeing" that CVC vowels are short.

3.2 Tutor Mode: Scaffolded Instruction

The objective of tutor-mode was enabling tutors to use PhonoBlocks as augmented paper-and-pencil. To that end, we provided tutors total control over the colour-codes and words the system displays. Tutors enter instructional words via the keyboard. By default, all letters are white. Tapping a hidden GUI button activates the colour-code selection panel. The panel enables tutors to activate a scheme. When a scheme is activated, PhonoBlocks re-colours the word according to the scheme and orthographic context. Tutors can therefore use the schemes to draw students' attention to the units of each decoding step as they explain the step. PhonoBlocks' multi-touch functionality enables tutors to flexibly segment the word into sub-units and play the sounds that correspond to them. Left-swiping letters "de-activates" them. Right-swiping letters re-activates them. Either change triggers the algorithm to re-colour the words as though the de-activated letters did not exist. (For example, de-activating "b" in "ble" would cause the algorithm to re-colour the "l" and "e' white). Tapping any active letter causes PhonoBlocks to read it and all adjacent active letters as though they were a word. These features leveraged the capacity of colour-changes to focus attention. De-activating a letter could cause the colours of its neighbors to change. For example, under the ST scheme, the "a" in "cat" is yellow. De-activating "t" converts "cat" into the open syllable, "ca". The algorithm immediately re-colours "a" red. Tapping "cat" would play short "a", tapping "ca" would play long "a". The correlated changes in colour and sound could help students notice the corresponding change in orthographic context.

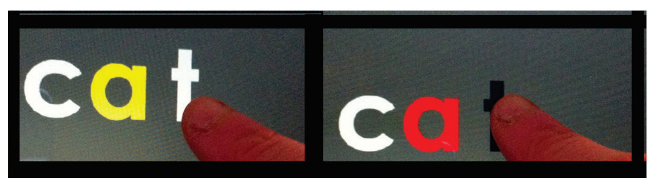

Figure 2. Multi-touch activation/deactivation helps students notice relations between syllable type and vowel sound

3.3 Student Mode: Scaffolded Transfer

The objective of student mode is helping students transfer knowledge from instructional to practice contexts. We programmed PhonoBlocks with different sets of practice words. Each set consists of words involving stable units or blends and closed, open or r-controlled syllables. Tutors can select which words a student sees. PhonoBlocks displays each word in sequence. All letters are white by default.

The student's objective is correctly segmenting the word into syllables. One design challenge was determining how PhonoBlocks would determine which syllables the student segmented. Multisensory classroom interventions require students to 'gesture' segmentation by circling around each syllable [4,6,8]. Accordingly, we required students to swipe circles around each syllable that they segmented. Swiping a circle around a syllable groups it. Tapping an onscreen button submits the group to PhonoBlocks. PhonoBlocks expects a specific set of syllables for every word. For example, for the word “cradle”, it expects “dle” and “cra”. Errors in segmentation are therefore errors in the submitted syllables. Errors can involve omitting or adding letters incorrectly. By analyzing these errors, PhonoBlocks identifies the step the student missed. For example, submitting “crad” indicates errors recognizing “dle”. Submitting “ra” indicates errors identifying the blend, “cr”. Submitting “rad” indicates both errors. PhonoBlocks reacts to errors in one or more decoding steps by temporarily and successively representing the word in each scheme for each step the student missed. Each colour-scheme appears for one minute, during which time PhonoBlocks does not react to input. After displaying the schemes, PhonoBlocks re-colours the letters white. At this point, PhonoBlocks allows users to re-submit their answer. The purpose of showing the colours was triggering students’ memories of the appropriate instructional sessions. The colour-codes thereby served as actionable feedback. The purpose of requiring students to correct their mistakes on uncoloured letters was encouraging them to abstract the knowledge the colours cued from the colours themselves, and integrate it with uncoloured letters.

An outstanding design challenge is how to reliably interpret errors in student’s pronunciations of words. Voice recognition is unreliable for children. At present, PhonoBlocks does not detect errors in students’ final pronunciations of words. Instead, for the final step of word pronunciation, PhonoBlocks enables students to temporarily activate the vowel-sounds coding scheme as a mnemonic device.

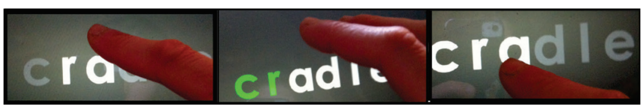

Figure 3. The colour codes tell the student that they failed to assign the whole blend (“cr”) to the first syllable (“cra”).

4. DISCUSSION & UPCOMING STEPS

We described a prototype software system designed to promote transference of syllable analysis from instructional to practice contexts by scaffolding instruction with visual cues that subsequently serve in practice contexts as actionable feedback and memory aides. Our prototype was a response to a general need for software systems that enable self-directed practice, and a specific need for features that support syllable-based decoding and integration with classroom knowledge. Our contribution was identifying colour as an interface feature that could support and bridge between instruction and practice and realizing it in a prototype system. PhonoBlocks remains a work-in-progress that we are iteratively refining through collaboration with domain experts and empirical research. Preliminary assessment with our domain experts suggests that tutors are enthusiastic to use PhonoBlocks. Our next step is evaluating how well the colour-codes support transfer to practice contexts with uncolored novel words.

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