Designing a Literacy-Based Mobile Application for Adult Learners

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CHI'16 Extended Abstracts, May 07-12, 2016, San Jose, CA, USA
ACM 978-1-4503-4082-3/16/05.
http://dx.doi.org/10.1145/2851581.2892397

Abstract
In this paper, we discuss the design of CAPITAL Words, an educational Android application to help low-literacy adults improve their phonemic awareness. We discuss our design choices concerning iconography, linearity, consistency, robustness, interactivity, and visibility when creating mobile software usable by illiterate users. We conducted a usability study with 11 adult learners at a local literacy center to determine how successfully users are able to interact with our interface. Results show that the majority of our design choices were intuitive for low-literacy adults with prior smartphone experience and highly learnable for inexperienced users, and that users overwhelmingly enjoyed using the app as a learning tool. This suggests that, if users are given a small amount of guidance initially, there is a high likelihood that they will be both willing and able to continue using our app independently to improve their literacy skills.

Author Keywords
Adult literacy; e-learning; interface design; low-literacy; mobile interface; usability

ACM Classification Keywords
H.5.2 [User Interfaces]: User-centered design; K.3.1 [Computer Uses in Education]: Computer-assisted instruction (CAI)

Introduction

According to the American Library Association, 14% of adults in the United States cannot "search, comprehend, and use information from continuous texts" [1], functioning with less than basic prose literacy. The National Center for Education Statistics has found significant overlap between adult illiteracy and certain demographic groups in the US, including non-whites and those with low income and low education [7]. According to a 2015 survey by Pew Research [3], at least half of the people in these three populations own smartphones: approx. 70% of blacks and hispanics; 52% of those with less than a high school education; and 50% of those making less than $30,000 per year. These same demographic groups are also some of the most likely to be "smartphone dependent": that is, their smartphone serves as their most reliable–and often times their *only*– way of accessing the internet. This makes smartphones an ideal platform for making learning resources available to these under-served individuals.

In this paper, we discuss the design of *CAPITAL Words*[1], an educational Android application designed for adults with the most minimal literacy skills, to help them improve their phonemic awareness through automatically-generated reading and spelling exercises that emphasize the relationship between words and sounds.

Several previous case studies have explored the challenges in designing software to assist illiterate populations with concrete physical tasks such as navigation [10], banking [12], healthcare management [9], and even SMS [5]. Many have explored how to design usable technology specifically for illiterate populations in developing countries, being especially mindful of unique cultural considerations when designing for intuitive use by these specific groups [6][11][14].

[1] http://letr.seas.gwu.edu/projects/capital.html

Figure 1: (a) Check and x-marks to denote correctness; (b) Right-facing arrows showing advancing screens; (c) Speaker icons to signify playable audio; (d) A 5-star meter to represent final score

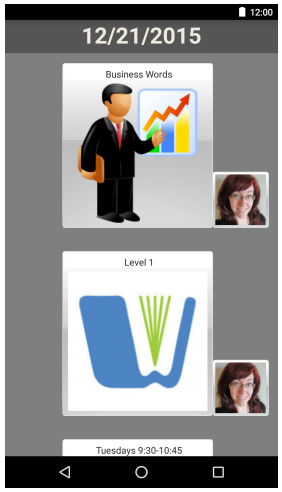
CAPITAL Words differs from these in two notable ways: first, our target audience is native English speakers, and second, our application is specifically educational in nature.

Because our software is designed to *improve* the user's literacy skills where others have focused solely on accommodation, we face a unique challenge in conveying more abstract learning-based concepts. The following sections describe the design choices we have found to be effective in conveying educational content in a minimal-text interface.

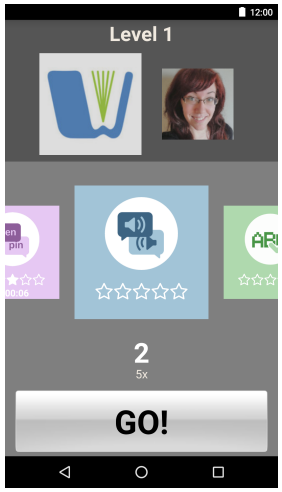
Iconography

We rely almost exclusively on images to represent ideas that a typical interface would convey textually. We leverage existing iconography wherever possible to convey high-level concepts: for example, a right-facing arrow is used to represent moving forward, and question responses are graded with checkmarks or x-marks to show correctness. Because we are designing for native speakers in the United States, we do not need to consider cultural influences when choosing our icons, unlike several other studies [8][10][13]. However, because low-literacy adults are most successful at identifying lifelike images [2], we avoid using overly abstract or minimalist picture representations of items.

Unfortunately, some concepts are simply too nuanced or unique to be easily conveyed through established icons.



(a)



(b)

Figure 2: (a) A scrolling list of Course cards, each with a unique image and an instructor photo; (b) The same image/photo displayed at the top of the Course page

For tasks such as these, we attempt to organically create a *paired association* between an image and what it represents. This pairing must be regularly reinforced in order to build an association through experiential learning. We avoid using images with possible conflicting associations: for example, we would not use a checkmark icon on an "accept" button, because we have already assigned the checkmark for response grading. When using an unfamiliar image to guide navigation, we reinforce that image both inside and outside the target view (see Figure 2).

Linearity

Following the recommendations of previous studies [4][12], we adhere to a guided linear design, organizing screens in a sequential order to guide users through tasks. Wherever possible, we minimize user input to a semi-persistent "continue" button which advances to the next screen. Users are able to simply move forward screen by screen to access and complete their learning materials, after which the next step "forward" will return them to the start of the next set of materials. Figure 3 illustrates the linearity our app's navigational tree.

This "forward" button navigation also allows for the flexibility of presenting *optional* choices. For example, each Lesson in a Course is unlocked in sequential order, leaving all previously-completed Lessons available to retake at any time. When the Course screen loads, the newest Lesson will always be selected and the user can simply click the button to begin. If the user wishes to take a different Lesson, however, they have the option to scroll to a previous Lesson card before clicking the button.

It is sometimes unavoidable to require users to choose their own path, breaking the linear structure. For example, users are often assigned to multiple Courses at once and must choose which Course to enter in order to access their learning materials. In this case, a "forward" button is not applicable, because there are multiple possible screens to advance to. In such cases, we remove the button from the view entirely and provide only the list of optional paths to choose from. Once a path is chosen, the button returns and the linear path resumes.

Consistency

Our goal is to minimize the user's cognitive load when navigating through the app. To accomplish this, we sacrifice modern minimalist aesthetics in favor of a high-contrast design, using consistent distinct stylings to clearly imply element functions and relationships. Consistency is particularly valuable in the following three design aspects:

Patterns. We apply a "glossy" gradient pattern to all interactive elements to help them stand out from their static surroundings. This allows users to easily recognize button components that can take them to a new screen, play an audio file, submit an answer, etc. This pattern can be applied to all colors and shapes to complement our other design choices.

Colors. Each exercise type in the app has an associated color which is used for all related components (background, buttons, card faces). These colors are reserved for exercise-specific elements and are not used anywhere else in the app. The prominent use of the color clearly informs the user of what type of questions they will be answering, which is useful for distinguishing between exercise types without written prompts.

Shapes. We use a rectangular card shape to represent elements that are "units" holding other elements inside (e.g. Courses, Lessons). By using consistent shapes and sizes for every card, we visually link them as being related: for ex-

ample, each Course card differs only by its images, showing that they are structurally identical but contain unique content.

Robustness

Wherever possible, we restrict users from committing mistakes that could interfere with their ability to use our software. For example, we override the device's hardware button behavior to prevent accidental minimizing/closing of the app, which was found in early prototypes to disorient and confuse users who often could not find their way back afterwards. We also use a system of *one-time authentication*, wherein a user needs only to sign in one time and then remains logged into the system indefinitely. There is no in-built mechanism for logging out: the user would have to manually clear the app's cached data in order to do so. This eliminates the possible barrier of a login screen and prevents accidental logging out, both of which could discourage a user from using the app.

When errors do occur, we must handle them robustly, because we cannot effectively communicate the problem to the user. For example, because our app requires an internet connection to send and receive data, we cache as much information to the device as possible to allow continued use if connectivity is lost. By fetching questions in batches and storing responses locally, we are able to save user progress even without internet access, eliminating the need to interrupt learning when a connection error occurs.

Interactivity and Visibility

Studies have shown that illiterate adults have weaker-than-average fine motor control [2]. To give the user an easier target and minimize their chances of misclicking unintentionally, we make interactive components large and prominent with obvious bounding boxes, and we include significant negative space between clickable components. We use radio buttons for answer selection, which Chaudry et. al. found to be the friendliest interactive widget for our target audience [4].

Low-literacy users have also been found to have a narrower field of view when presented with information [15]. As such, we strive to ensure that users do not become overwhelmed by too much information on a screen. If necessary, we divide content across sequential screens to minimize the amount in any one view. We ensure that any content the user may need is immediately visible, avoiding navigational widgets such as collapsible menus and pull-out drawers.

Usability Study

To test our app's usability, we invited 11 adult learners from the Washington Literacy Center (WLC) in Washington, D.C. to test the software in a guided study. IRB exemption was obtained for this study, but all subjects were willing volunteers and maintained anonymity throughout. 7 participants were men and 4 were women, and all were at the lowest level in the WLC curriculum. 7 students owned smartphones or were familiar with their use, and 4 had never used a smartphone before.

Prior to beginning, each student was shown a 5-minute narrated video outlining the purpose of the app, the concepts of Courses and Lessons, and how to think aloud for the study. We purposely did not explain *how* to use the app or complete any of the tasks.

Each student was given a separate user account enrolled in the same four Courses: the target Course and three "decoys." The target Course contained three Lessons with five questions in each. Students were asked to enter the target Course, complete the first two Lessons, and then retake the first Lesson again.

Smartphone Owners		
Task	**Before**	**After**
Scroll (V)	80%	100%
Enter Course	87.5%	100%
Radio Button	100%	100%
Scroll (H)	77.8%	100%
Course	63.6%	100%
"Go"	93.3%	93.3%
Speaker	87.5%	100%
Check/X	100%	100%
Arrow	98.7%	100%
Stars	100%	100%

Table 1: Percentage of successful attempts before and after the first error for smartphone owners

Non-Smartphone Owners		
Task	**Before**	**After**
Scroll (V)	44.4%	100%
Enter Course	55.6%	75%
Radio Button	82.4%	90%
Scroll (H)	50%	100%
Course	54.5%	90.9%
"Go"	100%	100%
Speaker	80%	100%
Check/X	95.2%	100%
Arrow	95.7%	98.7%
Stars	75%	100%

Table 2: Percentage of successful attempts before and after the first error for non-smartphone owners

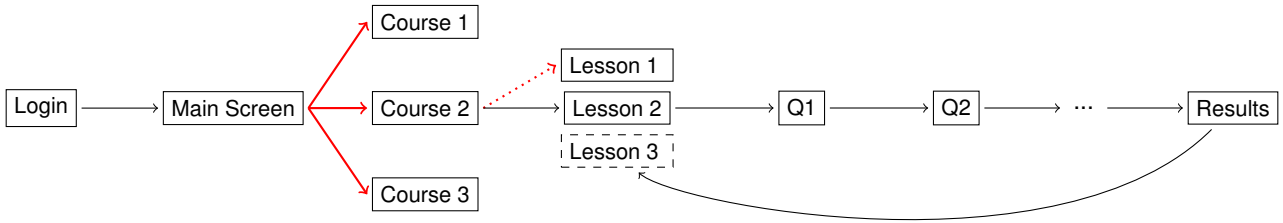


Figure 3: A navigational diagram showing the connections between each screen. Branching (red arrow) takes place only on the Main Screen, and optionally (dotted red arrow) if selecting a Lesson other than the default. Once all Questions in the Lesson (Q1, Q2, ...) are completed and the "end" screen is reached, the user is automatically repositioned to the next Lesson.

During this process, we recorded each user's successes and failures in completing 10 different tasks: four navigation-based (scrolling horizontally, scrolling vertically, entering a Course, and selecting a radio button), and six identification-based (recognizing and/or understanding the function of the target Course image, speaker icon, arrow icon, "Go" button, check/x-marks, and star meter). Successes and failures were identified by deliberate actions; unintended actions, such as accidentally tapping a button when scrolling, were not recorded. We also included verbalized thoughts in the failure counts, such as a student saying "I think this is it" while gesturing to a decoy Course.

Following the test, each student was also given an anonymous survey about their overall feelings using the app. Instructors administered the survey to each student in a private setting to encourage honest responses. Each prompt was read aloud to the student, and responses were given verbally following a 5-point scale from "strongly disagree" to "strongly agree".

Results

Quantitative

We recorded errors in the context of two different metrics: how *intuitive* our app is, and how *learnable* it is. We determine these measurements for each task by examining the number of errors committed before the first successful attempt and after the first successful attempt, respectively.

Tables 1 and 2 show the percentage of successful attempts within these two contexts for smartphone owners and non-owners. Tables 3 and 4 show the percentage of users from each group who failed each task at least once within each context. The results show that users with no prior smartphone experience struggled more to complete most tasks than users who owned smartphones, particularly with navigational tasks such as scrolling and selecting.

Horizontal and vertical scrolling proved to be the least intuitive navigation-based tasks for both groups of users, though they were both highly learnable for all users. Most users immediately understood how to interact with radio buttons, though some inexperienced users struggled with

Task	Phone (N = 7)	No Phone (N = 4)
Scroll (V)	14.3%	75%
Enter Course	14.3%	50%
Radio Button	0%	50%
Scroll (H)	28.6%	75%
Course	42.9%	75%
"Go"	0%	0%
Check/X	0%	50%
Arrow	14.3%	25%
Speaker	14.3%	25%
Stars	0%	50%

Table 3: Percentage of users who failed one or more times *before* their first success

Task	Phone (N = 7)	No Phone (N = 4)
Scroll (V)	0%	0%
Enter Course	0%	25%
Radio Button	0%	25%
Scroll (H)	0%	0%
Course	0%	25%
"Go"	14.3%	0%
Check/X	0%	0%
Arrow	0%	25%
Speaker	0%	0%
Stars	0%	0%

Table 4: Percentage of users who failed one or more times *after* their first success

the actual act of tapping. Several users struggled with figuring out how to tap a Course card to enter, and surprisingly, this also proved to be the least learnable task for inexperienced users, though experienced users learned this easily.

Of all the tasks requiring identification of element functions, the only one immediately recognizable to all users was the "Go" button. However, nearly all such tasks appeared fairly intuitive for both experienced and inexperienced users. Locating the target Course proved to be the least intuitive task for all users; despite being shown the target Course's image prior to beginning the study, more than half of the users failed to locate it on their first try. Being that the association between the Course and its image had not yet been formed, this was not unexpected. However, after successfully locating the Course once, nearly all users were able to do so again with no errors, suggesting that the association is learnable through repeated exposure.

Qualitative

The mean results of the opinion survey can be seen in Table 5. Several questions were repeated with opposite wording (e.g. "easy to use" and "hard to use") to ensure that students understood the meaning behind their rating. Three subjects' data were omitted because they answered such questions in a contradictory manor (e.g. giving 5 for both).

Despite the difficulties faced during the usability test, students responded very positively to the app. Students overwhelmingly agreed that it was enjoyable and easy to use, and most agreed that they would be able to keep using it independently.

Conclusions

The results of this study show that the majority of our design choices were intuitive enough to make our application usable by low-literacy adults with prior smartphone experience, though inexperienced users struggled with the majority of tasks at first. While our app was designed with smartphone owners in mind, we do not wish to discount the difficulties faced by those less familiar with smartphone technology. Future versions of the CAPITAL software will seek to further simplify troublesome tasks for both groups.

	Question	Average
(+)	Enjoy using	4.78
(+)	Easy to learn to use	4.78
(+)	Easy to navigate	4.56
(+)	Easy to use	4.11
(+)	Can use without help	3.78
(-)	Need more help to use	2.11
(-)	Hard to use	1.56

Table 5: Average student responses on a 5-point Likert scale, with 1 being "strongly disagree" and 5 being "strongly agree"

For both users with and without prior experience, however, the app proved to be extremely learnable once the correct methods were discovered. This suggests that, if users are given a small amount of guidance when first introduced to the app, there is a high likelihood that they will be able to continue to use the app independently to improve their literacy skills.

Acknowledgements

We thank the Washington Literacy Center[2] for collaborating with us in designing the CAPITAL Words software, and in particular the students who volunteered to participate in this usability study.

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