WordMelodies: Supporting Children with Visual Impairment in Learning Literacy

Sergio Mascetti[1], **Giovanni Leontini**[2], **Cristian Bernareggi**[1], **Dragan Ahmetovic**[3]

[1,2]Università degli Studi di Milano
Dipartimento di Informatica
[1]{firstname.lastname}@unimi.it
[2]{firstname.lastname}@studenti.unimi.it

[3]Università degli Studi di Torino
Dipartimento di Matematica
{firstname.lastname}@unito.it

ABSTRACT

We present *WordMelodies*, an inclusive, cross platform, mobile app that supports children with visual impairments in the acquisition of basic literacy skills through 8 different exercises. *WordMelodies* has been designed and evaluated by three domain experts in assistive technologies and education for children with visual impairments. After three design and evaluation iterations the app is fully accessible, except for one limitation of the cross platform development toolkit used.

Author Keywords

Visual Impairment, Education, Accessibility, Literacy;

CCS Concepts

•**Human-centered computing** → **User centered design;**
•**Social and professional topics** → **Assistive technologies;**

INTRODUCTION

Primary school educational tools are often not accessible for children with visual impairment or blindness (VIB) [3]. Indeed, textbooks are rich in graphical content, with the aim of engaging the students. However, this impacts their accessibility, even when they are available in a digital format. Similarly, educational apps often have inaccessible interactive graphical content, due to unsuitable design or sloppy implementation [7]. As a result, primary school education, including literacy skills is challenging for children with VIB [8].

To address these issues we present *WordMelodies*, an inclusive application to support children in the acquisition of basic literacy skills. *WordMelodies* was developed as a cross-platform mobile application and it includes 8 types of exercises. App analysis, design and evaluation were guided by three domain experts with a participatory approach. Following three design and evaluation iterations *WordMelodies* was considered to meet the functional requirements and to be fully accessible except for one issue, caused by the cross platform development toolkit, which we discuss in the following.

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ANALYSIS AND DESIGN

WordMelodies has been developed with a participatory approach, involving three domain experts: a teacher for children with VIB, a congenitally blind expert in assistive technologies (who is also a co-author of this paper) and a primary school teacher. During the analysis phase, we created a list of 59 suitable exercises to practice literacy skills in primary school. To define this list we collected data from domain experts, teaching standards [6] and analysis of the existing apps and websites. For each exercise, we provided an interaction example and collected subjective evaluation by the domain experts on the exercise usefulness. We then selected the 8 exercises with the highest average usefulness score to be developed in *WordMelodies*. Figure 1 shows examples of exercises, the complete set is available online[1].

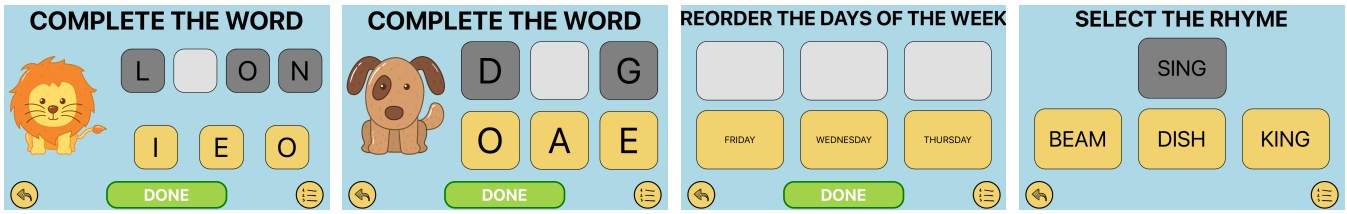
Another important aspect emerged while interacting with the domain experts: children in the target age group also need to develop key tech interaction skills [1]. In particular one expert remarked the importance of becoming familiar with Drag&Drop, a common gesture in mobile device interaction which is difficult to perform when using a screen-reader[2].

Based on this analysis, we defined the following criteria that drove the design and development phases.

- **Inclusiveness**. The app should be usable and easy to learn for children with and without VIB.
- **Entertaining**. Besides allowing the user to practice literacy skills, the app should also be fun and entertaining.
- **Independence**. The app should be usable by all users without requiring support from other people.
- **Consistency**. Key interaction elements should always be placed in the same part of the screen, possibly close to the screen corners or borders, where they are easier to find.
- **Beyond tap**. The app should use and teach common interaction gestures to children (*e.g.*, Drag&Drop). The gestures should be introduced and explained. Note that this is the opposite of the "simple gestures" principle defined in [5].
- **Scalable**. It should be possible to add new exercises and content with limited developing effort.

[1] https://ewserver.di.unimi.it/wm/

[2] With screen-readers, Drag&Drop is done by double tapping the object to drag, keeping the finger down after the second tap, then moving the finger and releasing when on the target. On iOS, it is also possible to select and move an app using the actions item on the rotor



(a) "Listen and complete" (lion) (b) "Listen and complete" (dog) (c) "Days of the week" (d) "Rhyming words"

Figure 1: Example of exercises in *WordMelodies*. Upon touching the animal icon, its call is played.

CROSS-PLATFORM DEVELOPMENT

Since our ultimate goal is to make *WordMelodies* publicly available to a large audience, we developed the prototype in *React Native*, a cross-platform developing framework [4]. Apps developed with this technologies can be deployed on both Android and iOS devices. Existing research show that it is possible to develop accessible apps with React Native, but in some cases native components need to be developed to overcome framework limitations [2].

In *WordMelodies* the user selects an *exercise type* from a list. Then, one *exercise instance* is shown, among the available ones for that type. For example, when the user selects "listen and complete" exercise type, one of the two exercise instances shown in Figures 1a and 1b is shown. If the user makes a mistake, *WordMelodies* gives a negative audio and visual feedback. Instead, upon entering the right answer, *WordMelodies* gives a positive feedback, it plays a short piece of music and shows the next exercise instance for the same type.

In order to enhance the scalability and to ease the creation of several exercise instances, we developed *WordMelodies* to have a clear separation between the code and the data representing exercises content. Indeed, the exercise instances are defined within a standalone static JSON file. Thus, adding a new exercise instance does not require to modify the app code. To further extend this principle, exercise types have been grouped into two *exercise classes*: those based on the use of drag&drop gesture and those based on multiple choices questions. The exercise types in the same class are actually run by the same code and only differ in terms of static content. For example, both "day of the week" and "listen and complete" exercises (see Figures 1c, 1a and 1b) belong to the same class (drag&drop), while "rhyming words" (Figure 1d) belongs to the multiple choices class. This further enhances scalability, making it easy to add new exercise types as long as they present the same interaction as the existing ones.

One of the main challenges during the development of the app was to achieve an accessible and easy-to-use drag&drop functionality. Indeed, no basic React Native component supports accessible drag&drop. Hence, it was necessary to implement a React Native component on both Android and iOS to provide audio information during drag&drop when screen reader is active. The aim was to mimic the drag&drop behaviour exposed natively by both Android and iOS (*e.g.*, when moving an app icon on the launcher). Rotor-based interaction, which is available only on iOS, was not replicated.

WordMelodies has been evaluated by domain experts across multiple iterations during the design and development phase. The iterative design approach gave us the opportunity to uncover and fix a number of issues and improve the overall app usability. As a result the application is currently fully accessible on both iOS and Android.

A single issue remains to be fixed: when exploring the UI elements with the flick gesture (*i.e.*, left/right flick to move to the previous/next element respectively) the order of the presented elements does not match the logical order of the elements on the screen. This problem is caused by the fact that React Native has an internal order of UI elements, and it is currently not possible to change the accessibility focus order of these elements. While this in part limits the app usability, it is still possible to completely explore the interface by scanning the screen with a finger.

CONCLUSIONS AND FUTURE WORK

Through participatory design and multiple evaluation iterations with three domain experts, we developed *WordMelodies*, a cross-platform mobile app that supports children with and without VIB in learning basic literacy skills. The app is designed to be entertaining, inclusive and usable without external assistance. *WordMelodies* is also aimed at improving children basic tech interaction skills and teach the use of common gestures, such as Drag&Drop which is difficult to perform using a screen reader. Currently 8 different exercise types are available, with multiple instances for each exercise, and new exercise instances and types can be defined without modifying the underlying app code. While the app is completely accessible, exploration using flick gestures is currently not supported by the cross-platform development toolkit.

As a future work we will involve children with and without VIB and their parents in the app design process, in order to better adapt to user needs and interests. We will also work on the development of additional native components for iOS and Android to make flick-based exploration possible and consistent across different platforms. We will add new exercises, a storyline as an edutainment container for the exercises, and entertaining audio-visual content to engage children. Finally, we will distribute the app to end users.

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