AMI: An Adaptable Music Interface to Support the Varying Needs of People with Dementia

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ABSTRACT
Dementia is a progressive, degenerative syndrome that erodes cognition, long term memory, and the ability to maintain social relationships. Anxiety is common among those with dementia, and ranges from momentary and mild, to chronic and severe. Listening to familiar music from childhood or early adulthood has been shown to provide therapeutic and positive quality of life effects for individuals with dementia, but most modern interfaces are unfamiliar and difficult to use which may add frustration and stress that music is intended to relieve. To enable individuals with dementia to control playback of music, we present AMI, a tangible music player that can be reconfigured and adapted to meet the changing needs and preferences of individuals. AMI provides a set of input components (e.g., buttons, switches, knobs) with varying physical properties which can be easily interchanged by a non-technical user (such as a caregiver). This work contributes the system design, results of user tests with the target population, as well as a set of design principles that can be used in the development of future interfaces.

CCS Concepts
H.5.2 [Information Interfaces and Presentation]: User Interfaces

Keywords
Tangible input; dementia; music and audio; accessibility; personalization.

1. INTRODUCTION
Over 46 million people are currently living with dementia, and this total is expected to double every 20 years [29]. Characteristic symptoms include disturbances of memory, thinking, and learning, as well as deteriorating emotional control [5], though the development and severity of symptoms is highly variable between individuals. Specific memories and abilities can be lost or altered as the syndrome progresses [4], which have adverse effects on quality of life, including depression [9, 18]. As dementia tends to occur later in life, people with dementia often cope with additional physical impairments. The combination of these factors can limit the individual's ability to perform certain actions or operate certain interfaces.

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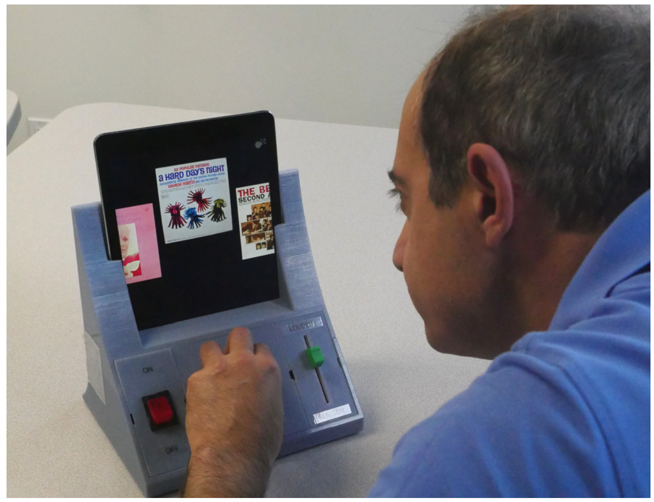

Figure 1: AMI, a reconfigurable tangible music player. By reconfiguring modules in the base, the player can be customized to a user's specific needs.

Listening to music has been shown to improve the mental state of people with dementia [14]. Touch based tablets and music players are commonly available to seniors [3], but are difficult for people with dementia to access independently [20, 22, 28], which adds to their stress and that of their caregivers. Traditional interaction design assumes that users will become more competent with practice, however, diminishing short-term memory makes this a challenge for people with dementia. To properly accommodate this population, new, adaptable hardware and software is needed.

To address these issues, we present AMI: an Adaptable Music Interface which provides a configurable, modular system that caters to the unique needs of users with dementia. This paper contributes a description of the AMI system and its implementation; observations from sessions where AMI was used by people with varying cognitive and physical impairments; and design guidelines for tangible and adaptable interfaces for people with dementia. While the current work is motivated by people with dementia, many of the concepts and principles are more broadly applicable to older adults, or those with various motor or visual impairments.

2. RELATED WORK
This work builds upon prior work developing technology and music interfaces targeted at people with dementia [2, 13, 15, 22] and is inspired by recent work in HCI which explores reconfigurable tangible interfaces. The development of AMI was guided by research into interaction difficulties of people with dementia [7, 11].

2.1 Music Interfaces for People with Dementia

With the increased interest in music as a therapeutic tool for people with dementia [1, 12, 19, 20] and for creating assistive devices for people with dementia [8, 14, 18], there have been a number of projects that aim to make music playback more accessible for this population.

One approach to accessibility is to use existing touch-screen interactions but cater the graphical elements to the target population [5, 10]. CIRCA, for instance [5] provides a touch screen interface that enables users to browse music and other media content with the goal of facilitating reminiscence therapy and providing access to content relevant to the user's history. Similarly, the ENABLE project [24] provides a touch screen interface for users to select music from a list interface and displays related lyrics and images to provide context for a song. While these approaches allow for some degree of customization in terms of the media that is played and presented, many applications on touch-screens are unfamiliar for users with dementia, and the physical actions (e.g., tap, swipe) themselves cannot be adapted to accommodate target users and their decreasing cognitive and physical abilities.

Other researchers have addressed the difficulty of touchscreen interfaces for older individuals and people with dementia by developing simplified tangible interfaces. For instance, INDEPENDENT [19] created a physical music playing device similar in size to a CD player. The device consisted only of a lid and a single button; this enabled the selection of music to a very limited extent, and could be used unaided by users even in advanced stages of dementia. However, this device and the various similar commercial products [24, 25] are not adaptable to a user or their changing needs, and provide only very limited control.

2.2 Configurable Interfaces

Within the domain of HCI, several research projects have developed systems which allow designers to quickly interchange and reconfigure input components to support rapid prototyping of interfaces. For example, Switcharoo and VoodooIO allow users to select components for each function of a system and position them anywhere they would like in order to control software [6,25]. Several commercial projects explore hardware-based approaches to prototyping, such as Phidgets [11] and Gadgeteer [26]. These approaches simplify hardware prototyping by standardizing an interface, allowing for plug-and-play abilities with a diverse set of components. Additionally, there are approaches that allow graphical user interfaces to adapt to the particular hardware they are being displayed on [10].

AMI builds on this work by adapting their use to the domain of media playback for people with dementia and simplifies the process of configuring inputs. By providing a set of standard components, and eliminating software configuration steps, AMI ensures that non-technical end users can readily exchange the input devices. The software allows AMI to map that functionality to the correct controls to enable a dynamic, adaptable test bed.

3. AMI

To address issues found in commercial media playback devices and research prototypes, we developed the Adaptable Music Interface (AMI). AMI is comprised of three parts (Figure 2): an iPad tablet, containing the music and acting as the display; input components, which are used to control the system; and a microcontroller, to translate the analog input into digital signals recognized by the software. Once configured with the help of a caregiver, AMI is intended to be usable by people with dementia and other impairments without assistance.

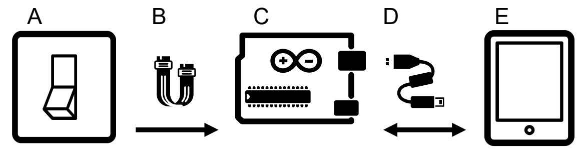

Figure 2: System overview: Input components (A) connect using ribbon cables (B) to an Arduino (C) in the chassis, which communicates via a serial cable (D) to an iPad (E).

It should be noted that the touch-screen functions of the iPad are used only by the caregiver during configuration. The tangible controls are used to operate the playback functions.

3.1 Input Components and Chassis

Thirteen modular input components have been fabricated to connect to a base unit. Each input component is comprised of an electronic device (such as a button, switch, or rotary encoder) mounted on a panel along with a 10-pin ribbon cable connector. Each panel contains alignment pins that provide stability and guide panel placement, allowing the components to be attached and removed easily. Panels can be 'single width' (5cm wide) or 'double width' (10cm) to facilitate a greater range of components. Panels can be attached to the chassis in any position and combination.

Each electronic device is directly wired to the connector. AMI utilizes six of the ten available pins, providing power, ground, an analog connection, two digital connections, and a "heartbeat" connection. Components can make use of these pins as needed, allowing users to connect analog and digital components without needing to understand the underlying electronic complexity.

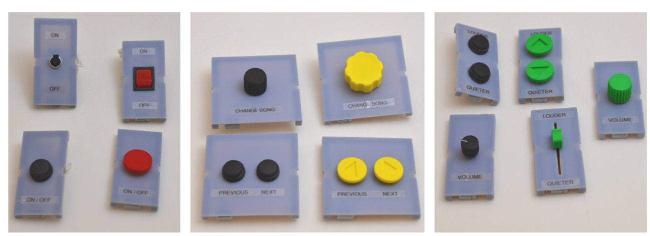

Figure 3: Modular components used with AMI. Left) power components; Centre) tuning components; Right) Volume

A wide range of input components are supported to increase the chance that users find a familiar control (Figure 3), or that a component will satisfy combinations of impairments. These components included professional, off-the-shelf devices such as knurled metal knobs, as well as several custom fabricated input devices that varied in color, shape, activation force, haptic feedback, etc. Currently, the system supports two types of toggle switches, several buttons, linear and rotary potentiometers, and rotary encoders.

The chassis (Figure 4, Left) provides power to the system and houses circuitry which manages the communication between the input components and the tablet application. Four 10-pin connectors are mounted within the chassis, and are wired to the analog and digital pins on an Arduino Uno. The Arduino polls these pins at 20Hz to monitor for changes in input values, and communicates with the iPad via using a Redpark serial cable [32].

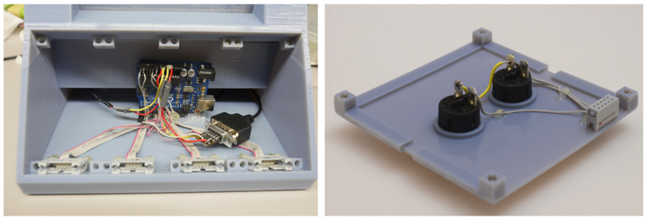

Figure 4: Left) Internal view of chassis, showing connectors and circuitry; Right) Wiring for sample input component.

3.2 Display and Audio Software

A custom iOS application runs on the iPad to provide functionality for media playback, display, and input handling. The application uses the existing iOS library for access to music the individual likes, and communicates with the attached Arduino using a serial connection.

When the system is in its *off* state, the tablet's screen dims and displays a treble clef, musical staff, and notes to provide a familiar visual indication of the device's functionality. When the system is in its *on* state, music immediately begins to play. Album art for the selected song is displayed in the centre of the screen, with *next* and *previous* tracks displayed to the left and right. When the selected track is changed (e.g. by navigating with next or previous buttons) the newly selected track rotates into place.

3.3 Configuration

To support the dynamic and changing needs of individuals, AMI supports simple reconfiguration of input components. When the tablet application opens in an unconfigured state, all functions are set to "safe" default behaviours (i.e., a random track will start playing at a pre-set volume, turning off after a pre-set time). Input components can be added or removed at any time into any position on the base unit while the application is running. An icon at the top of the display indicates what functionality a component will be mapped to.

To illustrate the utility of the configurable nature of AMI, we present a selection of sample configurations that could be designed for users living with dementia. (Figure 5) These configurations represent users presenting a variety of combinations of cognitive, motor, and visual impairments and show the spectrum of users supported with AMI.

4. FEEDBACK SESSIONS

To build an understanding of the utility of interchangeable controls, we conducted two informal feedback sessions with members of the target population (Figure 6). Sessions took place in two settings: an organized event for testing accessible products, and a daycare for people with dementia. In the former, the person with dementia was accompanied by a family caregiver, some of whom live with visual impairment; in the latter, a professional caregiver accompanied the person with dementia. Informed consent was obtained from all participants or their caregiver. In total, ten individuals participated in the study, with eight completing a personalized device. Two individuals stopped the session before completing a device.

We began by explaining the functionality of the system, and that it was a music player. Then, we presented AMI (or an auxiliary bank (Figure 6, left)) assembled with various input components. We asked the participant to use one of the components to achieve a desired functionality (e.g., turn on the device). Alternative components for that functionality were then presented to the participant, and they were asked to use them. If participants could understand and operate multiple components, they were asked for a preference, presenting them side-by-side for comparison. Once the participant selected one, the same process occurred for the next function (e.g., change song). When components for all functions had been selected, we presented the participant with a fully configured device to ensure they were able to use it.

4.1 Results

There were six unique configurations among the eight completed designs, and there were important individual differences between the devices constructed for each participant. For instance, one user did not understand the affordance of the large, yellow knob and tried to press it. Several others mistook some of the coloured buttons for knobs and attempted to turn them unsuccessfully. For these individuals, the availability of other components enabled them to configure a device that they would otherwise not have been able to use.

Figure 5: Sample configurations illustrating the adaptability to a variety of needs and use cases of fictitious, simplified personas. These examples serve to highlight how different components may support varied function, and are not meant to be a 'definitive' radio for any particular segment of people. The leftmost device may be used by someone without impairments (A), followed by an individual with cognitive impairment (B), visual impairment (C), physical impairment (D), and a combination of multiple impairments (E).

The utility of modular components was also apparent as participants' varied backgrounds impacted their preference and ability to operate the components. For instance, one participant, when asked how he would increase the volume with a knob, replied that he would "crank it up!". Further discussions with the caregiver revealed that the particular individual came from a musical background and was familiar with using knobs to control volume.

Figure 6: Individuals from each of the two sessions configuring AMI by testing components.

Overall, there was a broad coverage of input components used in the final devices. For power, four individuals selected rocker switches, three selected a toggle switch, and one chose a button. Knobs and buttons were almost equally preferred for song selection with five participants using buttons and three selecting knobs. Finally, the slider was the most popular volume component, used in four of the completed configurations, the others choosing a knob or buttons. This variation indicates that users could benefit from the ability to select and customize the input components.

Some users were unable to produce a configured radio by growing uncomfortable and ending the session early. This is not uncommon in dementia research, as individuals can become confused or anxious. In these cases, it may be worthwhile to provide indicators on the components that signal their functionality very clearly so the user may still be able to operate the device at a later time.

5. DISCUSSION

The results of the user study demonstrated the utility of the approach, and usability of the prototype. From the experiences we observed during the study, we present a set of recommendations to help guide future work targeting tangible interfaces for people with dementia. These recommendations build on existing work [7, 13, 18] as well as consultation with domain experts from four research groups and three care facilities. Many of the aspects described here are more broadly applicable to users who do not have dementia, but may have some form of physical or visual impairment.

5.1 Adaptation

Due to the variation between individuals with dementia, as well as the dynamic and progressive nature of the syndrome, it is important that interfaces which target this population are able to adapt to the specific person and their abilities over time [4]. Adaptation need not necessarily be automatic or accessible by the person themselves, but should be simple and intuitive as we found caregivers often have limited time to become familiar with a new interface and may be nontechnical. Adaptation should be possible not only at deployment-time, but also throughout the use of the device. If a user is no longer able to operate a specific functionality, that functionality should be removable or replaceable.

5.2 Familiar Metaphors

People with dementia often have varying experiences with devices (such as music players), and that experience may not be accurately remembered, so it is important to provide each person with interaction metaphors that are familiar [7]. To that end, familiar input metaphors should be used, such as flipping a switch, turning a knob, pressing a button, etc. Depending on the person's exposure to prior interfaces, they may better understand different metaphors (e.g., jukebox, 8-track, radio) and the associated controls. As the effects of dementia are widely variable [18], as much diversity should be supported as possible, e.g., differentiating form, action, and feel of each component.

5.3 Support Multiple Impairments

There are common impairments (loss of vision, motor impairments, etc.) which often concurrently impact people with dementia, as dementia tends to take affect at later ages. These impairments can prevent users from being able to touch or grasp small targets, operate high-force interfaces, or perform fine motor tasks. Additionally, visual impairments may hinder the user's ability to visually discriminate between the size, shape, or color of input components. To support a wide range of impairments, a system should attempt to provide a variety of input options and modes of feedback.

5.4 Limitations and Future Work

Improvements can be made in the software to allow for more complex mapping of functionality; e.g., a *configuration by example* approach where a component is connected and activated, then mapped to the next action made on the tablet such as decreasing the volume or pausing playback. Alternately, a touch-based interface that could be quickly used to map inputs to functionality could be useful to a caregiver or another user without dementia.

Additionally, the in-situ efficacy of AMI needs to be evaluated with a longitudinal study. This type of study would give insight into the utility of being able to reconfigure the device as the symptoms progress, and has the potential to provide new information to guide the design of future interfaces and technology.

6. CONCLUSIONS

Many individuals are impacted by dementia and its related effects, which cause a lack of independence and often with it depression and many associated afflictions. AMI aims to enable these individuals to control the playback of music using intuitive, tangible controls. With this type of interface, AMI intends to provide more independence and better access to music to people with dementia. The lessons learned while developing and testing the device can serve to inform the design of future devices targeted at individuals with dementia.

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