MusicalAid: A Playful Collaborative Music Tool for People Finding it Difficult to Handle Common Instruments

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ABSTRACT
MusicalAid is a tangible music system that allows people with different musical literacy and gross/fine motoric skills to play and create music together, either guided by a predefined rhythm or in a ‘free play’ mode. The system is composed of a main unit and a set of ‘instruments’, for example joysticks, a board with large buttons or soft interfaces like pillows with areas that act as switches. MusicalAid is designed so all instruments can at a basic level be synchronized to play to the same rhythm or beat, so they all sound at the same time. MusicalAid was originally developed for adults on the autistic spectrum with gross/fine-motoric limitations but MusicalAid can also allow people in general with different musical and motoric capabilities to play together. Therefore, MusicalAid enables a fun music experience for people that find handling traditional musical instruments challenging, or simply someone who just likes to jam.

CCS CONCEPTS
• Human-centered computing-Human computer interaction (HCI);

KEYWORDS
MusicalAid, autism, dementia, music, fun, collaborative, rhythm, beat, play

ACM Reference Format:

1 INTRODUCTION
Music can bring people together and playing music is considered by many to be a both fun and creative activity. Playing music together with others adds a social element that can help bring people closer together. Collaborative music playing promotes a sociocultural experience that involves an exchange of for example thoughts, feelings, and body expressions [5].

One core idea of MusicalAid is that all people should be able to play and explore music and to do it together. However, one quickly realizes that if a group of people play together, they must be able to follow the same rhythm. If that is not possible, it may still be fun, but it will not sound like a coherent piece of music to most people and in the long run it will be difficult to play specific songs. Reasons why people are not able to follow the same rhythm may be their lack of musical literacy, different gross and fine motoric skills or that traditional instruments (e.g. a string instrument like a guitar, a keyboard or a flute) are too complex to handle and learn. To address this challenge MusicalAid therefore has the option to, in a rudimentary way, synchronize the sounds from different instruments so even if the instruments are played at slightly different times, they will generate sound at the same time. MusicalAid can however run in two modes, the synchronized one just described and also in a free play mode where the instruments function as traditional instruments, i.e. a sound is produced directly when played without synchronization. Depending on the activity and the people using MusicalAid, one of the two modes can be selected.

MusicalAid is a music system developed to allow people to play music, individually or together in a group, regardless of for example their musical, intellectual, learning, and motoric capabilities. MusicalAid is composed of two main parts: A) The main control unit and B) instruments that people can play. Figure 1 shows the main unit and some example instruments. The instruments are rather different-looking compared with instruments like a guitar or keyboard. They are however purposefully designed to enable people with different physical abilities to use them. They do not sound by themselves, instead they send wireless instructions to the main unit that then plays a specific note or chord. The overall functionality can be described as follows: The main unit is Midi-based, has a speaker and can be set into different modes, for example can it be set to play a predefined drum-based rhythm (e.g. in 4/4 common time). The individual instruments communicate wirelessly to the main unit when they are played. The main unit receives these notifications and plays a note or chord immediately when notifications arrive, or it makes a simple synchronization of the note or chord with the current rhythm. If the main unit is configured to play the instrument-sounds in a synchronized mode, MusicalAid cannot guarantee that for example a song is correctly played, but all sounds will follow a defined beat and will therefore sound good at a rudimentary compositional level in that all sounds follow the same rhythm.

2 RELATED WORK
MusicalAid and its instruments does originally stem from work done with adults on the autistic spectrum. The system have thereafter evolved and been inspired by the ideas and philosophy of the Swedish instrument-maker Bunne [1, 9]. Bunne-instruments are analogue, simple to play and learn, and inclusive in their design.
Examples are the Swing bar guitar and the Monophonic flute. The Swing bar guitar is a four-string instrument with open tuning. It has a lever that can be tilted into four distinct positions that correspond to the standard D, A, G and E chords. People participate in playing songs on their own terms by striking the predefined chords following color-based instructions. The Bunne-instruments are often used with older adults, for example affected by dementia, but can also be used with children or other, and they are often part of a structured and group-based activity making the music collaborative and creates a shared experience.

In the digital realm, so-called sequencers are used to structure music and to construct songs and audioscapes. Systems have been developed to facilitate learning and musical explorations also by non-musicians, for example work on interactive musical systems [14]. Many of these systems are screen-based, but more experimental and tangible examples also exist. Physical computing systems like Drum Dino [6] also allow a user to build up structured sounds or compositions using the sounds of everyday objects (e.g. by having an actuator tapping a bottle every second). Existing tracks and music can also be controlled (e.g. turned on and off) by manipulating tangible blocks [4] or object floating in mid-air (e.g. a soundscape is controlled by manipulating a set of ping pong balls floating in a variable air-stream [2]).

Sequencers like LoopBlocks have also been design purposefully to be an Accessible Digital Musical Instrument Special useful in educational needs settings [8]. MaKey MaKey is another platform that allow people to play music using almost any object as an input device [12]. With MaKey MaKey a common banana can become a piano-key for example. MaKey MaKey allows for personalized instruments but does not offer additional support for playing together. MoosikMasheens targets a mixed-ability group context where young people with physical impairments or complex needs can explore music [11]. MoosikMasheens provides physical attachments to real instruments so they can be controlled digitally, including turning an acoustic guitar into an OpenSoundControl (OSC) controlled instrument. Commercial digital systems exist that allow people to explore, record and play music. Orba 2 is one example that through a small handheld device provides the opportunity to play and record music. When recording music Orba 2 can also be instructed to autocorrect notes that were played slightly out of sync with the set rhythm (i.e. quantization) [3]. Orba 2 and similar systems are feature rich and provide the musician many ways of playing and composing music. A recent product to support children with intellectual disabilities is Funki [7]. It seems Funki and MusicalAid share many design-ideas, for example on collaborative music making and Funki seems to be a very interesting system for playing music. Reading about Funki it seems their product is more controlling in terms of what sounds to play at specific times [10].

The above systems are examples of different forms of musical systems that in different ways explore how music can be created and played. Many of them are screen-based or depend on a computer. Others are pure self-contained physical computing systems built around microcontrollers. While some are designed for collaborative explorations, others are intended for single person use. MusicalAid share similarities with these systems, but also stands out as a tool for collaboration and creating shared experiences. Its design directly encourages people with different mental and bodily capabilities to explore and play music together. MusicalAid is developed to allow the creation of new music rather than the activation/deactivation of predefined tracks. A part from the base rhythm there is no playback or record capabilities. All music from the instruments is played live. MusicalAid is therefore a type of digital instrument that generates tones and chords when played (or slightly synchronized to the rhythm but that only inserts a possible small delay before a note sound compared with when it’s been played on an instrument) and not a sequencer that typically allows the musician to compose, record or playback a musical piece or in other ways activate predefined rhythms or sets of sounds.

### 3 TECHNICAL DESCRIPTION

MusicalAid, as explained above, is composed of a main unit and different instruments. The system offers a rich set of functionalities, but the core technical setup is as follows: The main unit (in the current version 1, see Figure 1, leftmost) is built into a 25*25 cm black casing with rounded corners and is 8 cm tall. Inside the casing there is a custom-made PCB built around an AVR microcontroller (see Figure 2). The microcontroller uses an XBee wireless transceiver to communicate with the different instruments. It is connected to a midi-Chipset that enables the main unit to play midi tunes. There is an integrated amplifier and speaker. The top of the casing is covered with a layer of multiple multi-colored LEDs followed by a semi-transparent plastic cover diffusing the light. The main unit is designed to be placed on a table with the group of musicians around it so they all can hear the music, see the LEDs and each other.

Each instrument offers a different interaction modality, using digital or analogue input. Each instrument is built around a PCB with an AVR microcontroller and is powered by a rechargeable battery for mobility and uses XBee wireless communication to send instructions to the MusicalAid main unit. Each instrument PCB can connect 12 different input sensors that will instruct the MusicalAid main unit to play a specific note or chord. The standard software
however supports 6 inputs and the additional six is used for configuration purposes (rather than hardcoding some settings). The instrument can be equipped both with analogue and digital input sensors and can thereby be tailored to specific needs, for example can an instrument offer richer expressions or just be a single, digital foot switch. Each instrument has an ID, and when a sensor is activated (i.e. a request to play a specific note or chord) the instrument transmits both the instrument ID and a sensor identifier (which of the possible sensors had changed state) to the main unit. Based on a lookup table in the main unit, the corresponding midi instrument and sound is played. Each message from the instruments to the main unit may be a request to play, manipulate or stop one specific note (e.g. C4 on a piano, or D3 on a trumpet) or a chord (for example an A7 or Dmoll chord from any of the available midi instruments).

Each instrument can send multiple signals to the main unit at the same time (e.g. a user can press two switches at the same time).

3.1 Features and modes of operation

Below follows short descriptions of MusicalAid’s main features and modes of operation.

3.1.1 Normal mode or synchronization. MusicalAid can work in two modes as described above: Synchronous mode or Normal mode. MusicalAid can also turn On or Off a basic drum beat that can guide the musician(s). As shown in Figure 3, in synchronous mode an instrument that is triggered ahead of the set drum rhythm becomes slightly delayed and is then played at the next set beat. In Normal mode this form of synchronization is deactivated and MusicalAid plays the requested note or chord as soon as an instrument is played on, like a traditional guitar or piano. It should be noted that this is a rather rudimentary form of synchronization, and does not include onbeat detection or more advanced forms of real-time analysis. This type of synchronization is often referred to in music as quantization and is a common feature when recording music. In a later processing stage a note or chord can be moved slightly forward or backwards in time to align perfectly with the set rhythm. As MusicalAid doesn’t record any music but everything is played live, this quantization or correction can only work in a forward-mode, meaning that if a musician plays their instrument slightly late, the sound will come first at the next beat. For a trained musician this may take some getting used to, but the idea is to provide people that lack sufficient gross and fine motor skills to get ‘extra time’ to set the ‘next note or chord to play’ if a specific song is played. MusicalAid allows ‘one beat of time’ to start playing a note or chord before it is actually played. Since the tempo can be set, this time can be rather long if needed.

3.1.2 LED instructions. The top of MusicalAid is equipped with two rings of RGB LEDs. Together the LEDs form 8 distinct positions in a 2-lined circle. The LEDs can be individually addressed but is typically turned on and off in a circular and clockwise pattern. Each LED position represents one beat in the set rhythm, typically 4/4. In this configuration, one full revelation (all LEDs being turned on and off once) corresponds to eight beats or two sets of 4/4 (see Figure 4).

One ring can be set to show the drum background rhythm and one ring to show what should be played (if the aim is to play a specific song using color coding). Being RGB LEDs they can be configured to assume any color, and the LEDS can therefore be adjusted for people who are color-blind or for other reasons may find it challenging to identify specific colors.

3.1.3 Type of rhythms. MusicalAid is currently configured to play either a standard 4/4 rhythm or a 3/4 Waltz rhythm.

3.1.4 Set speed and volume. Using two potentiometers on the front panel both the rhythm speed (tempo) and volume can be set. The built-in speaker also has a volume-controller.

3.1.5 Configuration display and 4 buttons input. MusicalAid has a small OLED display that shows a simple menu structure and current configuration. Using four buttons the user can navigate the menu and select/deselect different options. For example can different rhythms be selected, if the top LED display should be activated or not, and what kind of feedback-mode should be shown.

Figure 2: MusicalAid block
Figure 3: MusicalAid plays all instruments forward-synchronized (i.e. quantization) to the next beat in a defined rhythm OR instantly without synchronization in Normal mode.

Figure 4: Example LED feedback and instructions. In this example MusicalAid is set to play in 4/4 (see 'count' in the figure). Top row shows LEDs indicating the rhythm and that first the 'Red sound' should be played, and then the 'Blue sound'. Middle row shows rhythm, the specific sound to play (color coding) and when to shift to another sound. Bottom row shows the real MusicalAid system with different LED notifications: From left to right (Feedback turned off, Indicate to play 'Red sound' on beat, Indicate to play 'Blue sound' on beat, Play 'Green sound' & at next beat shift to 'Red sound'.

using the LEDs. The user can browse available color-coded songs and select one for playing. It is also from this menu that MusicalAid can be set to play in synchronous mode or to play all instruments instantly without considering correcting for the beat. The guiding drum beat can also be turned on or off from the menu.

3.1.6 Connect headphones. It is possible to connect external headphones to MusicalAid. When headphones are connected the built-in speaker is automatically muted.

3.1.7 SD Memory card. At the back of the MusicalAid main unit there is an SD card slot allowing a SD card can be used to store various configurations. The SD card stores all sound-mappings for the different instruments. For example, what note or chord should be played when a specific sensor on a specific instrument is activated. In this way an instrument may play some specific notes on a piano while another instrument creates guitar chords. The SD card also stores color-coded songs. A song is stored as a set of beats and each beat is indicated by a color that can be displayed on the top LEDs of MusicalAid when the song is played. These color-instructions can aid in playing the right note or chord at the right time. The SD card can also extend basic MusicalAid functionality. For example can additional rhythms be added (default is basic 4/4 and the 3/4 Waltz rhythm). These can later be accessed by the user from the control-buttons and screen. By storing all the above settings on a memory card a user can make changes, like adding more songs or changing the sounds on specific instruments, without reprogramming the microcontroller.

4 EARLY EXPLORATIONS OF MUSICALAID
MusicalAid has been explored with different people, including music therapists, but not yet with the intended target group. In a small, formalized experiment, two students and two student facilitators
When the tempo goes up, the adjustment or quantization becomes more evident. The above mentioned with some extra support-needs to play with musicians that can play differently and normal mode, both with and without LED instructions. While playing in ‘synchronization mode’ they found MusicalAid to be a bit frustrating and limiting their creativity. They didn’t feel a direct connection between their actions and the music that was actually played. When they played without synchronization, but still with visual cues from the LEDs they found MusicalAid to be a more interesting system and valued the color instructions. There is however a challenge in mapping the shifting colors on the main unit LED display and where the different ‘colors’ are played on the individual instruments. The change happens on the main unit but the right ‘color’ must be played on the separate units making it a hand-eye coordination issue. The focus in turned to the main unit that dictates what is to be played. Still, they found MusicalAid to be an easy way to express oneself as they do not risk creating disharmonic notes by accident. They also comment that when they change the tempo, and the beat is slightly faster, they get more emotions into what they play.

While they did not appreciate the synchronization, the forward quantization, they talked about it as something that could be useful for beginners or new bands to get going, to start explorations. They also tried the correction with different tempo, and they found the correction worked better for them when the rhythm was faster. When the tempo goes up, the adjustment or quantization becomes smaller and that gave another experience compared with a slow tempo where the correction becomes more evident. The above observations represent an early exploration and should be complemented with more explorations, especially with the intended users of MusicalAid. Being Work-in-progress MusicalAid has yet not been used by the intended target population but explorations like the above can still provide some knowledge, verify functionality, and so forth. Sessions with the intended users is a fundamental next step in the development of MusicalAid.

## 5 EXAMPLE USE SCENARIO

The MusicalAid system can be used in different use cases and scenarios. While it at this time has not been fully evaluated and tested, it has been demonstrated for the general public, it has been tried out and discussed with musical therapists and been tested with university students. MusicalAid is still to be used with user-groups that could benefit from its functionality.

A suitable use scenario would be a protected co-housing unit for adults on the autistic spectrum. The following scenario should be possible with the current functionality of MusicalAid. It is Friday afternoon before supper and not much to do at the co-housing facility. Most communal activities are rather passive by nature, like watching TV. Like many people, the small group of people living in the co-housing facility likes music. One is a rather skilled musician owning her own keyboard, while others do not really have any experience in playing music. One inhabitant uses a wheelchair and another one is both almost blind and restricted in his fine-motoric movements. MusicalAid allows this group of people to play together. MusicalAid is placed on the sofa table and the different instruments are selected by the people that like to play something together. One instrument is a soft pillow that the person in wheelchair can place in her lap. The visual impaired person gets an arcade-style joystick as an instrument. Each instrument allows the inhabitants to join in the fun. The girl who can play and owns a keyboard brings that out to the common area. She can keep a beat and can hence play together with the others but without using MusicalAid directly. The rock-type beat starts to play (generated by MusicalAid) and the group can now jam together. One play the drums, one a guitar and one make effect-sounds. Even if not all manage to hit their ‘keys’ at the right time, the system is forgiving and correct the timing so the sound is played aligned with the set rhythm. This time they were just jamming together, next time they decide to start practicing a song together. Maybe they can trick one of the staff-members into singing to their music?

Another example would be at a nursing home for older adults. Here a mix of people are living, some who can play an instrument, some that before could play but nowadays can no longer handle an instrument and then there are some that have no particular experience of playing music. They like to play ‘Happy birthday to you’ for one of the inhabitants that have their birthday. A staff member sets up MusicalAid and set the color-coding to guide the group in playing this particular song. The staff member cannot play any instrument and is not a trained musical therapist. However, the color codes provided by MusicalAid allow the staff-member to be the guide and conductor of the group playing. The staff-member says ‘Play Green’, and can then see that soon it will be the time to play ‘Red’ and can tell the group to prepare to shift to ‘Red’ and give the right cues in a timely manner. Here the color-coding of songs is not used directly by the people playing the instruments, but it allows a person not trained in music to guide a structured activity where a specific song is played. One just need to look at the MusicalAid LED display and help the participants by telling them what ‘color’ to play next.

## 6 DISCUSSION AND FURTHER WORK

There are many computer and Midi-based systems that allow people to either play music or to mix premade music and tracks in real-time. MusicalAid adds to this body of work and allows instruments to be designed for people with different capabilities and skills. MusicalAid can be used ‘as is’ or be used with a ‘director’ that guides a music activity – for example for structured group activities. MusicalAid can also be inserted in a larger context where standard instruments like guitar or a piano are played, where people are singing etc. In such a context. MusicalAid allows people with some extra support-needs to play with musicians that can play independently an don instruments that are not part to MusicalAid. One design consideration has been to allow people with diverse capabilities to make music that ‘sounds good’. What ‘sounds good’ is naturally very individual and contextualized. The ‘sound good’ is currently implemented as the opportunity to play together following a specific rhythm, allowing people to create something that sounds like one composition and not a variety of uncoordinated sounds. Also, the notes and chords have been selected to harmonize. There can clearly be many other interpretations of what ‘sounds
good’, and many other ways of implementing this but MusicalAid in its current version works as described above. Also, the reason why we play music may vary from person to person and situation to situation – MusicalAid however aims to support collaborative music activities following a set rhythm like 4/4 or 4/3. Future versions may explore other ways of playing together and making music that ‘sounds good’.

MusicalAid contains a rather rich set of functionality but lacks a proper user evaluation from its intended users. From the early evaluation with students it is clear that MusicalAid is not a ‘one size fits all’ musical system, neither is it intended to be. Compared with the students testing out the system the intended users are people with for example fine and gross muscle and coordination difficulties or people that for other reasons cannot play traditional instruments. It can be envisioned that there will be some experiments and testing to figure out how different groups or individuals like to configure and use MusicalAid. Someone perhaps likes to configure MusicalAid for a slow tempo, others a faster rhythm. Some will find the synchronization meaningful, while others may find it limiting, someone may require a highly individualized instrument design while others are fine with the existing example instruments, and so forth. The vision is that with future evaluations and design that MusicalAid can be what it aims to be – an aid – for people that find it difficult to explore music with traditional instruments.

In the next round of evaluation, it would also be useful to explore inclusive aspects where people playing traditional instruments can play together with someone supported by MusicalAid. In light of recent work by Spiel on norms and assumptions of the bodies we design while others are fine with the existing example instruments, it can be envisioned that with future evaluations and design MusicalAid can be what it aims to be – an aid – for people that find it difficult to explore music with traditional instruments. Also, the reason why we play music may vary from person to person and situation to situation – MusicalAid however aims to support collaborative music activities following a set rhythm like 4/4 or 4/3. Future versions may explore other ways of playing together and making music that ‘sounds good’.

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