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Melodica: An Affordable Music Companion

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ABSTRACT

Melodica is a situated robot we envision will help users practise mindfulness and overcome social disconnection through music. At a time when there are insufficient mental health resources, several AI tools have been designed to support people. Whereas these employ therapeutic practice, Melodica uses music as an approach to self-care. Music is a universal language, accessible to everyone, and helps to connect people from different cultures, age groups, and socio-economic backgrounds. Melodica is designed to be an inclusive and affordable robot that aims to accompany users and enrich their musical experiences, bringing people joy and solace to their everyday lives.

CCS CONCEPTS

• **Human-centered computing** → **Sound-based input / output**; *Accessibility design and evaluation methods*; • **General and reference** → *Design.*

KEYWORDS

Human-Robot Interaction (HRI), mindfulness, music, interoperable design, affordability, inclusive technologies

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1 INTRODUCTION

With an ageing population and the increased prevalence of single-person households, social disconnection has become a widespread concern. Social disconnection can harm people's physical and mental health [2, 3]. In this paper, we present the idea of using an affordable music robot 'Melodica' to mitigate social disconnection and improve users' physical and mental health.

Melodica, our music companion, derives its name from the combination of the Latin words for 'melody' (*melodiam*) and 'friend' (*amica*). It is a situated robotic agent with song and lyric search capabilities, sound-activated light display and robotic movement. A combination of these features aims to create an immersive musical experience. Thus, users may employ Melodica to generate a suitable atmosphere to help them reflect on their feelings, practise mindfulness, enjoy the present moment, and learn about music in other languages and from other cultures.

Figure 1: The first physical prototype of Melodica

Shown in Figure 1, the initial prototype is comprised of two cardboard boxes. The main body encloses the processing unit, cables and battery, with a speaker built into the front, and a power button and charging port at the back. To each side of Melodica, there are two arm accessories, and four wheels are attached to the bottom. The head component encloses a digital display on the front and a microphone on the top. It is decorated with LED lights (although they are drawn on in the prototype). Melodica is a simple mobile robot made of low-cost materials and electronic components.

We will first explain why music robots are useful, then talk about Melodica's design principles, functionalities and use cases that differentiate it from existing assistant-like products. Finally, we will discuss its implementation and manufacturing process.

2 WHY DO WE NEED A MUSIC ROBOT?

In recent decades, social disconnection has become a common concern worldwide. Such disconnection refers to social isolation that makes people lack social, emotional or physical contact with others [7]. It is either objective or perceived, or both [14]. Aside from the social disruption brought about by COVID-19, the causes of social disconnection also include getting older [17] and living alone. Social disconnection can lead to many physical and mental health conditions, such as an increased risk of heart disease, stroke, dementia, and higher rates of depression, anxiety and suicide [2, 3]. The impact of social disconnection on health has attracted much attention recently due to COVID-19 self-isolation protocols [4, 16, 18]. Living in an increasingly disconnected society, how can people create connections with themselves, others, and the world?

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It seems that music could be the answer. Music is known for improving people's emotional state and overall mood [1], helping us strengthen our social resilience and recover from mental stress [13]. It can encourage people to reorient their attention on their emotions and the present moment, which is the core idea of mindfulness [5]. Several studies have shown the effectiveness of mindfulness-based music therapy (MBMT) [8, 19]. In addition, music creates connections across time and space. It can trigger memories and evoke powerful emotions [20]. For elderly people who are not able to recall the past, music has therapeutic value [12]. Specific music can also increase functional connectivity [9]. Moreover, music is a universal language regardless of age, culture, ethnicity or socio-economic background. Thus, music seems like an inclusive means for practising mindfulness and building connections with oneself, others and the world.

Society faces uncertain times, with insufficient mental health services and heightened demand for qualified therapists. This problem worsens in low-income countries[15]. In response to these concerns, various e-mental health tools have been developed, such as AI-driven Cognitive Behavioural Therapy chatbots and wellbeing applications [21]. These tools are more affordable and accessible than traditional mental health support; and may allow users to be more comfortable sharing their struggles [10, 11]. On the music service side, there are also numerous websites, software and apps that allow for playing, discovering and streaming music. However, there are several prevalent limitations within each of these product spaces that may represent gaps in the market:

- Poor Cross-Lingual Support: users may find it difficult to access music in different languages or from different cultures.
- Limited Modalities: most products do not offer a multimodal music experience like tactile effects.
- One-Way Interaction: current systems cannot play music without explicit real-time instruction.
- Lack of Integration: users need to switch between different music apps/products to find out information about a song.
- Limited Mobility: users need to carry music products around when they move.

In response to the above limitations, we propose a music robot 'Melodica'. We hope Melodica will deliver an enhanced musical experience with rich sensory effects and flexible interaction modes. As a supplement to conventional therapy, this lighthearted approach to self-care allows users to set up a joyful or relaxing environment where users may practise mindfulness by enhancing self-awareness and enjoying the present moment. This will also facilitate users to connect with themselves and others through time and space. Furthermore, Melodica's physical embodiment and situational embeddedness are key to increased user engagement and successful human-robot interactions (HRI) [6].

3 WHAT CAN MELODICA DO?

On board with the theme of 'HRI for All', Melodica has been designed with these principles in mind:

- **Inclusive Music Content**: We seek to include a wide range of music from different cultures, under-represented populations, and even 'music' from the animal world.
- **Flexible Music Delivery**: Apart from listening to music, Melodica could enable users to experience it in other ways. For example, through lights, robotic dance movement and vibrating wearable accessories.
- **Personalised User Experience** with:
  - > Accessories like robotic arms, or personalised embodiment like a rabbit, or a seal.
  - > Atmospheric light projections (e.g., bubbles, starry night).
  - > Voice modulation (e.g., robotic, echoey, cartoon-like).
  - > Functional modes. For example, an 'education' mode would allow users to learn about different instruments. A 'health' mode would allow Melodica to play a specific type/piece of music when users experience distress. A 'Follow Me' mode would allow Melodica to follow users around.

The following list introduces the basic functionalities of Melodica that can be implemented using current technologies.

- **Voice User Interface**: Rather than manual clicking or typing, Melodica can recognise and respond to users' verbal commands (e.g. play a song).
- **Basic Search Function**: It can perform standard search functions to search for a specific song, a type of song, and retrieve relevant song information via services like the Google Assistant API[1] and the Genius API[2].
- **Basic Display Function**: Lyrics and song information can be displayed on the LCD screen.
- **Basic Lighting Display**: Colourful and sound-reactive lighting can be shown via strips of LED lights.
- **Standard Robotic Movement**: It can move around on a flat surface via four sturdy wheels.
- **Detachable Arm Components**: It has exchangeable actuating arms affixed to its main body.

In the design process, we considered extended functionalities for Melodica. These are desirable and also more complex to implement.

- **Advanced Music Search**: Allow users to (i) identify a song by analysing a short audio segment from a piece of music being played[3], the user's humming or the whistling of a song's melody[4], (ii) search for songs by analysing both the melody and lyrics (e.g., a cheerful song about breaking up), and (iii) discover new music with similar styles[5], even across different languages.
- **Advanced Lyric Display**: This involves (i) translating lyrics to display the song in different languages, (ii) showing how the lyrics sound in a given alphabet/script, and (iii) generating a summary in your preferred language of what the lyrics convey. This function could be useful for language learners with different purposes.
- **Advanced Light Display**: Melodica can be integrated with smart home lighting to create a more immersive atmosphere.

[1]Google Assistant has built-in Automatic Speech Recognition (ASR) and Natural Language Understanding (NLU) capabilities.
[2]Genius is the world's biggest collection of song lyrics and musical knowledge. Its API gives access to songs, which are represented as music lyric documents.
[3]Developers can use open-source tools such as the ShazamKit or the Shazam API.
[4]Google Assistant allows the user to search for a song by humming the tune for 10-15s.
[5]MusicStax discovers new music by analysing a song's theme, and other data features.

- **Advanced Robotic Movement**: The robotic agent can follow the user upon request when they move around (e.g. to another room). Other mobility options are (i) rhythmic movement of individual components (i.e., head, arms and wheels), (ii) coordinated head, arm and wheel motion for dancing capabilities, and (iii) moving hair (plastic filaments) that rises when music becomes more intense or loud, mimicking the human experience of goosebumps.
- **Environmental Responses**: Melodica may work with smart apps and sensors to make decisions or suggest actions that relate to the users' wellbeing. It can be programmed to (i) inform users of potential harm when loud music has been played for an extended period, (ii) take regular breaks from using the sound-activated lights if users are prone to seizures or epilepsy, (iii) reduce the volume when it detects people are talking to the user, (iv) play appropriate music for users who are experiencing periods of stress, panic or other unpleasant symptoms (e.g., seizure) by working with other health apps, and (v) make the bed-time music fade out by working with sleep monitoring apps which can tell when users fall asleep.
- **Wearable Accessories**: Hearing-impaired users might find access to this technology difficult, so we thought about using wearable accessories that buzz/vibrate to the music's rhythm.
- **Richer Sound Database**: Music is not just songs. Other sounds can create immersive experiences, affect our emotions, and allow for self-expression. We hope to include sounds of nature, animals and instruments from around the world in our musical database to appreciate the diversity of the world.
- **Conversational User Interface**: Melodica could play music quizzes with users in a conversational style to provide further educational value (e.g., identify animal or instrument sounds).

4 APPLICATION SCENARIOS

Several scenarios have been described below to help visualise how Melodica can provide a real-life utility. Example scenarios weave Melodica's core and extended functionalities into a short timeline, where we describe 'A Day with Melodica'.

i) UNWINDING WITH MELODICA: Anthony wakes up on a rainy Saturday. Today his family is visiting him and he would like to cheer up and enjoy his downtime before the kids wake up. Anthony enables Melodica's sound-reactive lights and requests 'a relaxing playlist of Autumn music hits'. Combining the calm music and the soothing light display helps him unwind and feel relaxed.

ii) LANGUAGE LEARNING: While Anthony is getting food ready, he decides to practise his Spanish skills. He would like to learn simple songs that match his language ability but are not too childish. Thus, Anthony asks Melodica for some "traditional and simple Spanish songs". After listening to a few suggestions, he comes across the 'Macarena Dance' he likes. Later, he enquires about the story behind the song. Melodica searches and tells Anthony how the pop duo 'Los del Río' were inspired to write this song.

iii) MELODICA, THE PARTY-GOER: Anthony's parents arrive, and the party begins! The kids start a karaoke session by searching for fun music and asking Melodica to display the lyrics on-screen. Melodica jiggles its head and wiggles its actuating arms to the music's rhythm. The room becomes an atmospheric space as the robot is connected to the smart home light system.

iv) 'FOLLOW ME!' MODE: After a successful party, it is time to clean the aftermath. Anthony would like to listen to motivational music to help him get through this tedious task, but he doesn't want to carry his phone or speakers around. Thus, he enables Melodica's 'Follow Me!' mode, so the music follows wherever he goes.

v) CONNECTING CULTURES: Anthony's kids are doing their homework in the evening. They have been asked to search for Chinese songs that they enjoy. They would like to find a similar song to 'My Way' by Frank Sinatra in Chinese. They ask Melodica to discover new music based on these criteria, and the robot reports similar Chinese pop ballads.

vi) BEDTIME WITH MELODICA: Later at night, Anthony is putting his kids to bed. He asks Melodica to connect to a sleep monitoring app and play soothing nature sounds until the kids fall asleep. This will help the kids calm down and fall asleep.

5 ROBOT DESIGN PROCESS

Melodica is inspired by interoperable technologies, which include computer systems or software that can work with external products and systems [22]. This section details Melodica's interoperable design and outlines the reasoning behind our choice of hardware components and manufacturing process.

5.1 Hardware Implementation

The hardware design employs a Raspberry Pi (RPi), a low-cost CPU-based single-board computer, for processing and connecting to external components. The RPi has adequate power and memory to handle the execution of the robot software (written in Python), and interfacing with different I/O hardware components and online services, it will allow us to implement our proposed functionalities. Wired connections (e.g. GPIO pins[6]) will be used (over wireless) for connecting to components together to reduce latency and ensure a robust connection. Access to online services will depend on a Wi-Fi connection, therefore, the user must still have Internet access for Melodica to function. The design has been chosen to be both affordable and fit within the constraints of our resources.

Below we introduce our choice of hardware components that allow us to achieve Melodica's desired functionality.

- **Processor**: Serves as the 'brain' of the robot. A Raspberry Pi 4 with 2GB RAM will be used and it costs £51.50 on PiHut[7].
- **Speaker + Microphone**: A mini stereo speaker (£10.90) will be employed to play music. A mini microphone (£5.20) will be used to capture user voice commands.
- **Digital Display**: A 16 x 2 I2C Liquid Crystal Display (LCD) (£14) will be used for outputting textual information. Alternatively, for a higher price, we could use a touchscreen display as an additional control interface.
- **Lights**: A flexible strip of RGB LED lights (£11.40/metre) will be used for audio-reactive lighting effects.
- **Motors**: Motors will be used to control actuating components, and we opt for push header motors (£5/unit) for easy assembly.
- **Battery**: A rechargeable power bank that powers the RPi (£31).

[6]GPIO stands for General-Purpose Input/Output signal pins.
[7]All hardware components can be bought at The PiHut: https://thepihut.com/

Figure 2 depicts our hardware implementation, giving an overview of how the components connect together.

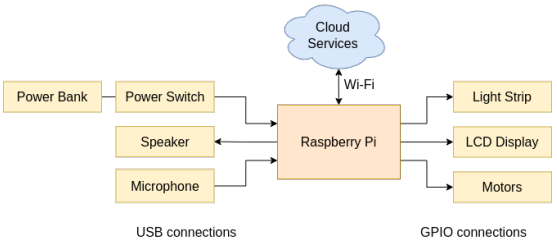

Figure 2: Hardware Components Diagram for Melodica.

5.2 Appearance & Manufacturing Process

Our design is intended to be easy, affordable and scalable to manufacture, using sustainable materials where possible. Following our preferred hardware implementation, the external components of Melodica are as follows:

- **Main Body**: The main body will house the internal hardware and wiring, and is envisioned to be formed of laser-cut pieces of wood-based materials, such as plywood (4mm plywood at £2/sheet). Neutral colours are preferable since we want to appeal to a wide audience, and bright colours can give commercial products a childish appearance (e.g. Marty the Robot).
- **Head component**: The head will encase the LCD screen and microphone, and will be formed from laser-cut wood pieces.
- **Mecanum Wheels**: The motors will attach to mecanum wheels (£4.70/unit on The PiHut) underneath the main body to facilitate omnidirectional movement. We preferred wheels over mechanical legs, since they provide more stable movement.
- **Arms and Accessories**: Actuating components can be made using 3D printing facilities and 3mm acrylic (£0.49/sheet). A CAD model for the components will be generated, and then the 3D printer forms the design. Plastic is not a sustainable material, however this method allows us to easily form various components for personalisation purposes.

Our prototype of Melodica (Figure 1) shows the feasibility of connecting our hardware components together and brings our vision to life. The modular and flexible nature of our hardware design allows for features to be added incrementally. However, the software implementation for desired functionalities could not be achieved due to time constraints. Future work will primarily involve writing software and manufacturing components.

6 CONCLUSION

We have proposed an affordable and inclusive supplement to conventional therapy by designing and building a prototype of Melodica, which aims to increase users' social, emotional and physical engagement via an immersive music experience.

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