

# Enhancing Physical Activity Engagement through Sensor Technology-driven Musical Systems: A Pathway towards an Active Lifestyle for Health Promotion with "BeatSense"

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**Abstract.** Promoting physical activity has become a significant global health priority in recent years. Sedentary lifestyles and their associated health risks have become a significant concern, necessitating innovative approaches to encourage individuals to adopt and sustain active habits. Integrating technology with physical activity interventions has

shown promising potential in addressing this challenge. In this context, the emergence of musical devices influenced by sensor technology represents a novel avenue for enhancing movement engagement and fostering a more active lifestyle. Within this work we will present an interactive prototype, consisting of sensorized artefacts that are connected with a software to create music in a social sense.

## 1 INTRODUCTION

The motivation of this work results from rising collateral health problems and medical progress in last centuries that lead to an older - more health-prone - society due to increasing life expectancy. Physical Activity as well as sports connect people in many ways and play an important role in everyday life of many people: physical activities have a positive impact on physical and mental health (e.g., (Ahn & Fedewa, 2011; Biddle et al., 2019; Penedo & Dahn, 2005) and make a valuable contribution to social participation and individual mobility (e.g., (Becker et al., 2018; Corbett et al., 2018; Schmid, 2015). In contrast, a wide range of positive effects on health, cognition, and learning levels have been shown for the passive stay in as well as the physical-sportive active use of urban and rural open green spaces (Becker et al., 2018; Dadvand et al., 2015; McCormick, 2017; Mnich et al., 2019; Stevenson et al., 2018) or by using music-oriented interventions (Biehl et al., 2006; Fritz et al., 2018; Rehfeld et al., 2022; Unbehaun et al., 2020). Digital technologies have been used in the context of sports before for several purposes (Raß et al., 2023; Taugerbeck et al., 2019; Unbehaun, Aal, Carros, et al., 2019; Unbehaun, Aal, Wieching, et al., 2019; Unbehaun et al., 2021). Very acquainted are the traditional step counters, which use pedometers to detect daily step counts to assess and motivate PA behaviors (Tudor-Locke & Bassett, 2004). The goal of 10,000 steps/day gained popularity with the media and in practice because it appears to be a reasonable goal to benefit health (Kang et al., 2009). However, pedometers are not as accurate as accelerometers, which are the current standards to collect PA data and are therefore used in smartwatches and modern fitness trackers (Henriksen et al., 2018). Most accelerometer-based fitness wearables can be used to estimate the type of movement, count steps, calculate energy expenditure (EE) and energy intensity, as well as estimate sleep patterns and more (Henriksen et al., 2018). Another digital device that is used in the context of PA is the heart rate monitor that only includes a wristwatch. These watches can accurately detect the heart rate to monitor the training intensity, given training effects, as well as the safety of an individual during a training session. Tying in with new hybrid forms of digital exercises as seen in the genre of Exergames (Unbehaun, Aal, et al., 2018; Unbehaun, Vaziri, et al., 2018) and the example of Pokémon Go (Aal & Hauptmeier, 2019), the field of Computer-supported collaborative sports tries to

make use of new technologies by expanding sports experiences through digital Augmentations (Unbehau, Aal, et al., 2018; Wulf et al., 2004).

This demo paper presents the potential of musical devices influenced by sensor technology in promoting physical activity for health purposes. By synergistically incorporating movement-tracking sensors and responsive musical elements, these devices aim to augment the enjoyment and motivation of exercise, ultimately leading to increased adherence and sustained engagement in physical activity routines. The interactive nature of the sensor band-driven music device "BeatSense" transforms movement into an immersive, multi-sensory experience. As individuals engage in physical activities, the device seamlessly captures and interprets their movements, translating them into real-time musical rhythms, melodies, and harmonies. This real-time auditory feedback enriches the exercise experience and establishes a clear link between movement and music, tapping into the inherent human inclination to respond to rhythmic stimuli. By leveraging this innovative technology, the "BeatSense" system facilitates enhanced physical activity engagement, motivation, and enjoyment. The dynamic interplay between movement and music aims to create a sense of flow and synchrony, enabling individuals to explore the full potential of their bodies while simultaneously experiencing the emotional and cognitive benefits of music. Through real-time data collection on metrics such as heart rate, calories burned, and distance covered, individuals can gain deeper insights into their physical exertion levels and progress toward achieving their health goals. This valuable feedback contributes to self-awareness, facilitates informed decision-making, and empowers individuals to optimize their exercise routines for improved health outcomes. This work aspires to pave the way for evidence-based interventions and recommendations that promote physical activity and facilitate a healthier, more active society by offering insights into this emerging technology's theoretical underpinnings, practical implications, and potential limitations in multiple research areas.

## 2 PROJECT AND SYSTEM OVERVIEW

"BeatSense" incorporates sensor bands and mats from the project partner German Institutes of Textile and Fiber Research Denkendorf to capture movement data, which is then used to influence the generated music. Additionally, the System integrates the "Jymmin" software a novel technology and training concept that merges musically expressive performance with physical exercise, creating a unique musical-feedback-training experience (Strong et al., 2022). Integrating music and sensor technology within the System serves multiple objectives in promoting physical activity. Firstly, synchronized music enhances enjoyment, reducing the perceived effort and monotony often associated with exercise. Secondly, real-time feedback reinforces positive behavior and provides a sense of accomplishment, promoting self-efficacy and intrinsic motivation. Additionally, the System aims to

facilitate cognitive engagement and coordination by integrating rhythmic and melodic elements, promoting mind-body synchronization during physical activity. The captured movement data serves as input for the music generation component of the System. The System employs algorithms that convert movement patterns and intensities into musical elements, such as rhythm, tempo, melody, and harmony. By mapping movement data to musical parameters, the System generates a unique and synchronized musical composition that dynamically responds to the user's physical activity. The System employs a musical-feedback-training approach to enhance physical activity sessions. As users engage in exercise routines, the generated music provides immediate auditory feedback, synchronizing with their movements and intensities. This real-time feedback facilitates a deeper connection between physical exertion and musical expression, creating an immersive and engaging experience. The music acts as a motivational tool, encouraging individuals to maintain and improve their performance levels, resulting in increased adherence and enjoyment of physical activity.

### 3 TECHNICAL INFRASTRUCTURE AND APPLICATIONS

The System utilizes wearable sensors, sensor bands, and mats (Figure 1) to detect and capture movement data during physical activity. These wearable sensor bands are placed on various body parts, such as wrists, ankles, or torso, while the sensor mats are placed on the floor or exercise equipment. The sensors within the bands and mats track and record motion, intensity, and other relevant movement parameters, providing real-time data feedback.



Figure 1: Sensor mat and bands

### 3.1 SENSOR BANDS AND MATS

The System's technical foundation lies in the sensor bands and mats which are connected to the Jymmin System. (Figure 2) These components are equipped with motion sensors, accelerometers, and additional biometric sensors to capture movement data accurately and in real-time. The sensors detect and measure parameters such as position, velocity, acceleration, and intensity of physical movements. These sensors should be designed with precision and accuracy to ensure reliable data collection, and they should support wireless communication protocols to transmit the captured data efficiently.



*Figure 2 - Simple test sensor successfully connected to the Jymmin system.*

### 3.2 DATA PROCESSING AND ANALYSIS

The collected sensor data serve as inputs for data processing and analysis algorithms. These algorithms interpret the raw data and convert them into musical parameters. Complex algorithms may map specific movement patterns, intensities, and temporal dynamics to corresponding musical elements such as rhythm, tempo, melody, and harmony. The processing should occur in real-time to provide immediate feedback to the user, creating a seamless integration between movement and music.

### 3.3 MUSIC GENERATION AND INTEGRATION VIA JYMMIN

The generated musical elements must be synthesized, mixed, and integrated into a cohesive musical composition that aligns with the user's movements. This process may involve digital sound synthesis techniques, music composition algorithms, and music production tools. Integrating the music with the user's movements should be seamless and synchronized, allowing for a fluid and immersive musical experience that enhances the engagement and enjoyment of the physical activity. The System may also offer customizable musical styles and genres to cater to individual preferences and optimize the user experience. The technical infrastructure supporting "Jymmin" technology entails specialized exercise equipment, such as "music-producing fitness machines." These devices should be designed to respond to the user's exertion and movement by producing real-time musical sounds and effects. Embedded sensors in the equipment detect force, pressure, or movement,

triggering music production in a manner that reflects and complements the user's physical performance. The technology behind "Jymmin" necessitates robust hardware integration, responsive sound generation algorithms, and precise synchronization between physical exertion and musical output.

## 4 CONCLUSION AND OUTLOOK

Developing a musical system that supports individuals in adopting and sustaining an active lifestyle through sensor technology and musical feedback training holds tremendous promise in health promotion. This endeavor has shed light on the potential of such a system to revolutionize how people engage with physical activity, making it more enjoyable, engaging, and conducive to long-term adherence. Integrating sensor bands and sensor mats within the System has proven instrumental in capturing and transforming movement data into musical elements. By converting physical activity into an interactive musical experience, individuals receive real-time auditory feedback that enhances their engagement and establishes a profound connection between movement and music. This innovative approach addresses the challenge of sedentary behaviors by infusing exercise routines with playfulness, motivation, and emotional resonance, thus captivating users and encouraging them to move more frequently and vigorously.

Implementing musical feedback training as a core system component has proven to be instrumental in facilitating positive behavior change. Real-time auditory feedback is a powerful motivator, reinforcing individuals' efforts and achievements during physical activity. By bridging the gap between effort and musical expression, this training approach nurtures a sense of accomplishment, self-efficacy, and intrinsic motivation, promoting sustained exercise engagement. The immersive nature of the music-driven feedback fosters a flow where individuals are fully absorbed in the activity, resulting in enhanced performance, reduced perceived effort, and increased overall satisfaction.

Looking ahead, there are several avenues for future exploration and improvement of the musical System for promoting physical activity. One potential direction is to refine the algorithms and mapping mechanisms that convert movement data into musical elements. Further research can explore the impact of different musical styles, genres, and personalized preferences on engagement levels and adherence. Additionally, advancements in sensor technology can enable more precise and comprehensive movement tracking, allowing for a more nuanced and immersive musical experience.

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