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参加型協奏体験に向けたアクセシビリティ対応デジタル楽器の基礎検討

A Preliminary Study of the Pentatonic Space: An Accessible Digital Musical Instrument for Participatory Ensemble Experiences
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概要: 音楽は人と人をつなぐ参加型行為であるが，鑑賞中心の消費が進み，共同演奏の機会が減少している．本研究は，多様な身体からの音楽参加を支援するアクセシビリティ対応デジタル楽器の設計を目的とし，左右手間距離をペンタトニックスケール音に変換する「Pentatonic Space」を試作した．座位／臥位など姿勢条件が演奏体験に与える影響を予備的に評価した結果，好ましい演奏姿勢や手の動かし方については参加者間で大きく異なる可能性が示唆された．今後は多様なユーザが複数人同時に利用できるよう，インタラクションとシステムのデザインを改良する．

キーワード： Accessible Digital Musical Instruments, Body Positioning, Human-Computer Interaction, Music Technology

1. Introduction

For millennia, music has served as a fundamental tool for social bonding and human cooperation [1]. However, contemporary society has witnessed a shift from participatory to commodified music [2], where music making has transformed from communal activities to individualized consumption [3, 4, 5]. This commodification threatens traditional social functions of music making [6] and represents a loss of fundamental human rights to expression and belonging [7].

Recent developments in digital musical instruments (DMIs) and accessible digital musical instruments (ADMIs) offer means to restore the social aspect of music-making in a digital age [8, 9, 10]. However, current ADMI research indicates a need for improved accommodation of diverse user needs, particularly in terms of physical disabilities and accessibility design [11, 12, 13, 14, 15, 16].

This paper addresses the specific gap of user-friendly design in ADMIs, focusing on body positioning during musical interaction. The research question is: *How can digital musical instruments be designed to accommodate different bodies through positioning of users better and thus offer access to music as a form of embodied communication?* To investigate this, we developed "The Pentatonic Space," an ADMI that explores how grounded positions (sitting versus lying) affect musical engagement and user fatigue.

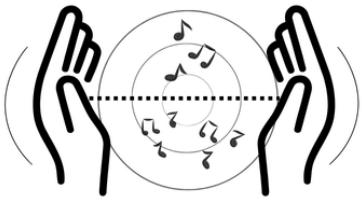

図 1: Hand movement interaction design for distance-based sound control.

2. Concept Design

2.1 ADMI and Accessibility

Digital musical instruments (DMIs) combine human computer interaction and musical interface design [17]. Accessible digital musical instruments (ADMIs) expand this field through adaptability and customization [12], though current research lacks sufficient focus on contextual accessibility needs and participatory design [16, 11].

2.2 Theoretical Framework

The concept design draws on three established design principles from HCI and digital musical instrument research (Figure 2): intuitive interaction [18], collective

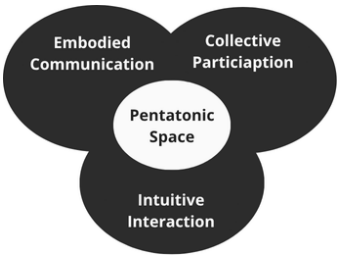

図 2: Design Principle of the Pentatonic Space

participation [18], and embodied communication[1]. Regarding collective participation, the current ADMI in this paper does not support multiple users. Instead, it seeks to broaden its accessibility by expanding what might be understood as a collective, such as different bodies and people that might require a more flexible design approach from ADMIs.

2.3 The Pentatonic Space

The created ADMI is dubbed the Pentatonic Space, and is a concept where audio-visual responses to physical movements allows for a embodied music-making experience that seeks to utilize the digital and physical dimension of ADMIs to increase accessibility of music-making. The pentatonic scale is central to its design, with which it was deemed easiest for the widest possible variety of participants to create harmonies.

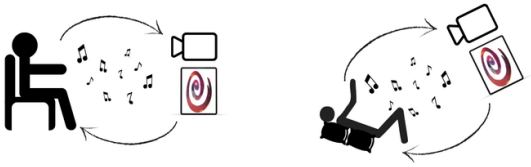

図 3: Body Postures: (a) sitting setup and (b) lying setup.

3. The Prototype

3.1 System Design

The system creates a camera-based instrument where hand movements trigger sound generation within a pentatonic scale, with users controlling sound by varying horizontal hand distance. The camera tracks hand positions and translates movements into pentatonic scale variations, chosen for its intuitive interaction properties demonstrated in early musical training [19]. The system accommodates sitting and lying positions as illustrated in Figure 3, with hand movement interaction shown in Figure 1, using one camera, one screen, and headphones to host one person at a time. The ADMI is dubbed the Pentatonic Space.

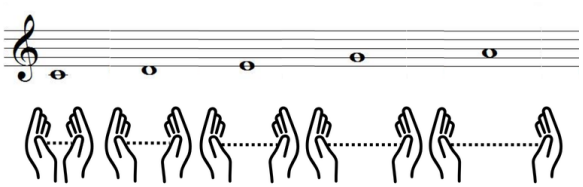

図 4: Sound mapping visualization showing the relationship between hand distance and pentatonic scale generation in the VCV Rack synthesizer system.

3.2 System Architecture

The system architecture (Figure 5) creates a real-time hand-to-sound interface where a webcam captures hand movements, MediaPipe processes tracking data, TouchDesigner converts positions to musical control, and VCV Rack generates pentatonic scale audio output where hand distance maps to pentatonic scale pitches (Figure 4).

4. Preliminary Experiment

To examine the interactions of the musical device prototype, we employed an iterative design process, utilizing user feedback.

4.1 Experiment Setup

Based on preliminary findings that identified hand fatigue during horizontal hand movements while sitting, this experiment was designed to test whether changing user position from sitting to lying down might reduce hand movement fatigue while maintaining the musical interaction experience (Figure 6). We asked four participants to test both sitting and lying positions within the same session using a counterbalanced design. Each participant was allocated five minutes per position but could end at their discretion. Post-interaction interviews captured comparative feedback on fatigue levels, comfort preferences, and interaction experience. The participants' age group ranged from 22 to 33, and all were graduate students.

4.2 Results

According to the findings, the results were mixed regarding the hypothesis. P1 confirmed the fatigue reduction when lying down, reporting the experience was *"very much better"* with significantly reduced hand fatigue. The participant noted that lying down shifted their attention from the visual screen to focusing *"very much more on the music,"* creating a more immersive auditory experience. However, P2 contradicted the hypothesis, expressing that *"sitting is better than lying down"* and found sitting *"the most comfortable."* This participant reported that *"lying down makes me more tired"*

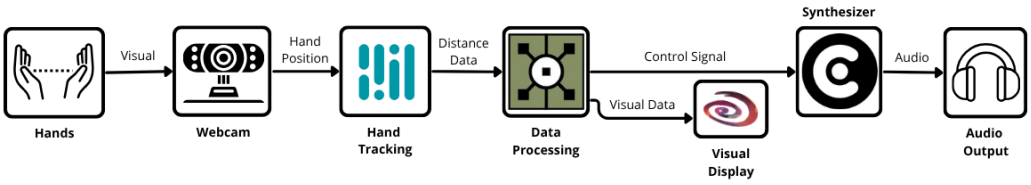

図 5: System Architecture: Real-time hand-to-sound interface pipeline showing dual output paths from TouchDesigner

図 6: Experimental setup showing participant positions: (a) sitting position and (b) lying position.

and felt they could achieve *"more accuracy"* when sitting. During the lying-down experience for P2, we observed positioning issues where they held their hands vertically above their bodies, as shown in Figure 7. This resulted in consistently elevated arms that couldn't rest during interaction, which may have contributed to increased fatigue rather than reducing it.

5. Discussion

The preliminary findings validate existing literature regarding the critical importance of flexible interaction design in accessible digital musical instruments. The preliminary findings validate existing literature regarding flexible interaction design in accessible digital musical instruments. The Pentatonic Space prototype demonstrates varied body positioning preferences among users, with mixed results showing that digital musical instruments must accommodate diverse preferences to achieve true accessibility [12].

These conflicting positioning preferences directly support established research showing that expression within digital musical instruments can be restrictive when designed with limited interaction approaches [11]. The findings reinforce that spatial preferences and individual differences are crucial considerations when designing ADMIs for broader accessibility.

5.1 Spatial Design Insights

The observation that one participant held their hands vertically above their body when lying down, creating increased rather than reduced fatigue, provides valuable spatial design insights. This unintended positioning demonstrates the importance of considering how users naturally adapt to different configurations in ADMI design.

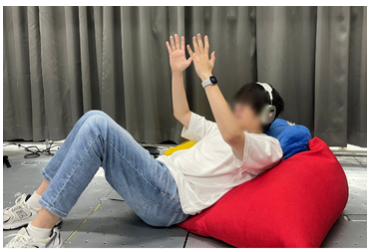

図 7: Hand positioning during lying-down interaction showing elevated hand placement above body.

5.2 Design Process Insights

The findings demonstrate that body-space relationships vary significantly among users, with no single positioning approach proving universally superior. This highlights a critical challenge in ADMI design: many digital musical interfaces restrict interaction to one predetermined mode, potentially discriminating against users whose bodies or preferences don't align with that singular approach. The design process reveals that creating inclusive music-making spaces requires accommodating multiple interaction modalities simultaneously, embracing user differences rather than enforcing standardization. This approach aligns with core accessibility principles that recognize true inclusion requires adapting systems to human diversity, not the reverse.

5.3 Technical Limitations

Technical limitations in camera positioning and hand tracking intermittency, while constraining optimal performance, provide insights for future system improvements. The current setup's focus on individual interaction also highlights the need for collaborative experience development.

5.4 Future Development

The next step will focus on improving prototype structure through refined sound design, optimized spatial arrangements, and better camera positioning to accommodate different body positions more effectively.

6. Conclusion

This paper investigated how spatial positioning affects user interaction with accessible digital musical instruments through the Pentatonic Space prototype. Our preliminary experiments comparing sitting and lying-down positions among four participants revealed mixed positioning preferences, validating existing literature that emphasizes accessible digital musical instruments must accommodate diverse user preferences rather than adopting standardized approaches. The findings demonstrate that spatial preferences and individual differences are crucial considerations in ADMI design. Observing unintended hand positioning during lying-down interactions provided valuable insights into spatial design challenges, reinforcing the importance of flexible interaction design approaches. Future work will focus on developing multi-user adaptive systems accommodating various positions simultaneously and incorporating larger participant groups including individuals with special needs. This research contributes to understanding spatial design considerations in inclusive music-making technology and explores music making as a social task in a digitized age.

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