Body Music: Physical Exploration of Music Theory

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Abstract

Music is appreciated by people from all walks of life. Music fits into our daily schedules in many ways, from casual listening to cultural events or movies. At a deeper level, the mechanics of music are not usually known to most lay people and learning the components of music theory can be a lengthy and difficult process. We present a new paradigm of social musical exploration and creation system using the physical body as an interface. We have created a physical mixed reality interactive game which enables people from all walks of life to interact in a physical space and learn fundamentals of music theory through experimentation. The initial prototype teaches pitch, time signature and dynamics in music. Initial player studies were conducted to refine the prototype to improve the usability, playability, and to ensure that the learning objectives are accomplished. We provide an evaluation of the research project and assess the usefulness of the system in the classroom setting as well as an interactive museum setting. Future plans for development are discussed in the conclusion of the paper to provide for the future development direction.

CR Categories: H.5.5 [Information Interface and Presentation]: Sound and Music Computing—Signal analysis, synthesis, and processing; J.5 [Computer Applications]: Arts and Humanities—Literature

Keywords: serious games, physical computing, music

1 Introduction

In this digital age, new interfaces for musical expression provide much broader musical possibilities than have ever existed before. There is a constant quest to be in harmony with ones instrument so that music can flow freely from the imagination and take form effortlessly. This sparks an interest to achieve more fluid methods for creating music, particularly in the use of the human body as the direct interface with music.

There are many new digital musical interfaces, but most are based on traditional musical instruments or are at least designed as a tangible object. In the music computing community there is an increasing attention on identifying new paradigms of expressive interaction with machines. Camurri [Camurri 1995] argues that one of the most consolidated directions is that of interactive music systems, i.e. systems able to process expressive gestures for generating and controlling musical signals, such as hyper and virtual musical instruments [Machover and Chung 1989].

Attention of the music community is focused on the development of interaction metaphors that take into account full-body movements and gestures at different levels of abstraction, and the interaction with an active environment with evolution and dialogue capabilities. This leads to Multimodal Environments enabling multimodal player interaction by exhibiting real-time adaptive behaviour [Castellano et al. 2007]. In particular, immersive environments enabling communication by means of full body movements, such as in dancing, singing, and playing. Movement and music are intertwined for two reasons. Firstly, sounds are made when air vibrates at frequencies, which are sensed by the ear. In order to generate the vibration, a mechanical movement is necessary. Faster vibrations yield higher pitch and likewise, more pronounced vibration yields higher volume. The second aspect relating movement to music is the natural tendency for people to follow along with music by moving their bodies. Dance not only echoes the music, but helps the dancer understand the music in a more emotionally deep manner. Quite simply, sound is made by movements; people understand sound by moving.

The goal of this research project is to blur the line between these two aspects, and open up an avenue for them to mingle more intimately. Instead of dancing to music, it is now possible to create music by movement. This project is a tool, an interface between motion and music, a new musical instrument. It is designed to be highly configurable to allow the artist as free a form of expression as possible. It is also designed to be fun and comfortable to use. This is a powerful tool and a fun toy, stimulating for adults yet accessible to a child.

2 Background

Currently, children or adults who wish to learn music must do it through the traditional musical instrument such as the piano, violin or drums. However, it is helpful to remember that these musical instruments are merely means in which a variety of sound or musical notes are produced.

Though there are obvious benefits in the use of these instruments in facilitating the acquisition and sensitization to music, it often necessitates certain mastery, or at least an acceptable level of competence in the musical instruments in order to bring about an appreciation of music itself. Beyond this, each musical instrument is designed to produce its unique sound and therein foregrounds a distinctive aspect of the musical score. Even though there is merit in this, there is nonetheless a certain reduction in capacity and constraint in full expression for a musical score when a single particular instrument is used. For instance, the same tune will carry a different quality, and as a result a dissimilar feel, or emotional experience, when played by a guitar, organ or harmonica.

While there could be indignant protests from traditionalists who might uphold the importance of learning music through musical instruments, it is an undeniable fact that the technicalities and com-

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plexities involved in the mastery of a musical instrument could have put one too many potential music enthusiasts off. There are innumerable individuals, who confronted by the challenge and seemingly insurmountable hurdle of mastering a musical instrument, simply gave up and gave in to the familiar reason that they are just not musically inclined.

This, however, could not be further from the truth. Humans are musical beings. We make music all the time and apart from the situation of silence in a vacuum created by an artificial void, sound is an indelible part of the human experience. It is a part of our lives. As such, there is an imperative to be sensitized to the nature of music, its frequency, pitch, volume, rhythm, and from there, cultivate an appreciation of music.

3 Related Work

There is also a growing trend of playing music video games. Guitar Hero is a good example that has found its way into most popular game consoles like PlayStation 2 & 3, Nintendo Wii, and Xbox 360. The game is notable for the introduction of a simplified musical interface which is a scaled down version of a guitar. This interface offers a gentle learning curve and does not require knowledge of playing the real instrument.

Commercial arcade games have recently seen a growing trend of games that require human physical movement as part of the interaction. For example, dancing games such as Dance Dance Revolution (DDR) and ParaParaParadise by Konami are based on players dancing in time with a musical dance tune and moving graphical objects. These dancing games introduce performance as a key element in the play experience. It is a new kind of entertainment where the game player also doubles as a performer. The dance movements introduced by the game have a performance element which attract the audiences attention and amusement. However, these games still force the person to stand in more or less the same spot and focus on a computer or TV screen in front of them.

Our game promotes full body movement over a large space rather than restricting the player to a small area. This encourages the players to explore the game space together with other players. We also maintained the performance play element of the above mentioned games. This is especially useful in classroom learning, for non players to be immersed in the game and to understand the game by watching others play.

Recently, there are new musical interfaces that allow users to create and manipulate music through touch and drawing using tangible musical interfaces [AsiaOne 2008]. One such example is the TENORI-ON by Yamaha [Yamaha 2007]. TENORI-ON allows the user to create musical performances by touching and drawing patterns on the box-like interface. Our system extends the box-like interface to a full sized room space which allows users to utilize their bodies as an interface to create and manipulate music.

Our research extends on the Eurythmy [Steiner 2008] concept of visualising language and music in a form of body movement. When performing Eurythmy with music (also called tone Eurythmy), elements of music for example melody, harmony and rhythm, are all expressed. We take the reverse approach to the Eurythmy concept by allowing players to explore the music theories through their body movements and interaction with the other players in a physical space.

4 Learning Objectives

The objective of this research project is to transcend the limitations presented in the use of musical instruments as the essential interface for learning some core elements in music theory.

The level of knowledge of the concepts of frequency, tempo, and volume among others are only learned after the student internalizes the mechanics behind the concepts. Our learning objective is to provide an interactive experience in which the student gains an understanding not from learning in traditional methods or through hours of practice. Our objective is to more quickly break down some of the fundamental concepts of music theory and allow the student to touch and feel the variables much like pulling the levers of a machine and experimenting with the possible outcomes and therefore develop a deep appreciation and understanding.

4.1 Accomplishing the Learning Objectives

Our research project endeavors to address and eliminate the hard to learn interface of traditional musical instruments. Our aim is to make the person one with the interface. We want people to experience, interact and manipulate music directly, without the need for a steep learning curve. By allowing control and manipulation of musical notes through the human physiology, barriers to learning music are removed. The project promotes learning of music by allowing the individual to experience how music is created through their bodily movement and physical actions.

This project aims to eliminate the physical instrument altogether. The sensor system enables the use of ones own body as a musical instrument through detection of movement, freeing the artist from the traditional requirements of producing live music. The ability to create and manipulate sound through movement provides the potential for immediate intuitive control of musical pieces.

In this paper we describe a game, which allows players to use their full-body for controlling in real-time, the generation of an expressive audio-visual feedback.

5 System Description

The system extracts expressive motion features from the players full-body movements and gestures in a room setting as shown in Figure 1. The values of these motion features are mapped both onto acoustic parameters for the real-time expressive rendering of a piece of music, and onto real-time generated visual feedback projected on a screen in front of the player. This intuitive way of exploring music provides a deeper sensitization of the nature of music itself, such as frequency, amplitude, tempo and time signature, and hence lowers the barriers in appreciating music. This can also inspire more people to learn music and music theory as well as develop newfangled approaches to music. Details explaining the proposed learning objectives and the ways in which the system accomplishes these are provided in the following sections.

5.1 System Architecture

Our system consists of the following four components: playground, camera, speakers and visual output screen. A playground can be any floor space that is within the camera viewing area. A normal web cam is used for tracking of the players activity in the playground. The system is developed using MAX/MSP programming platform and the video tracking is done using the Cyclops plugin. The MAX/MSP program developed is shown in Figure 2. The reason we chose MAX/MSP is due to its ease of reprogrammability which is one of the key design considerations for our system. Figure 3 shows the system in operation with the video tracking and Max MSP program running on the laptop screen and the visual output on the right. Figure 4 shows the camera tracking matrix for the scenario of 2 people and with a resolution of 5 levels for each

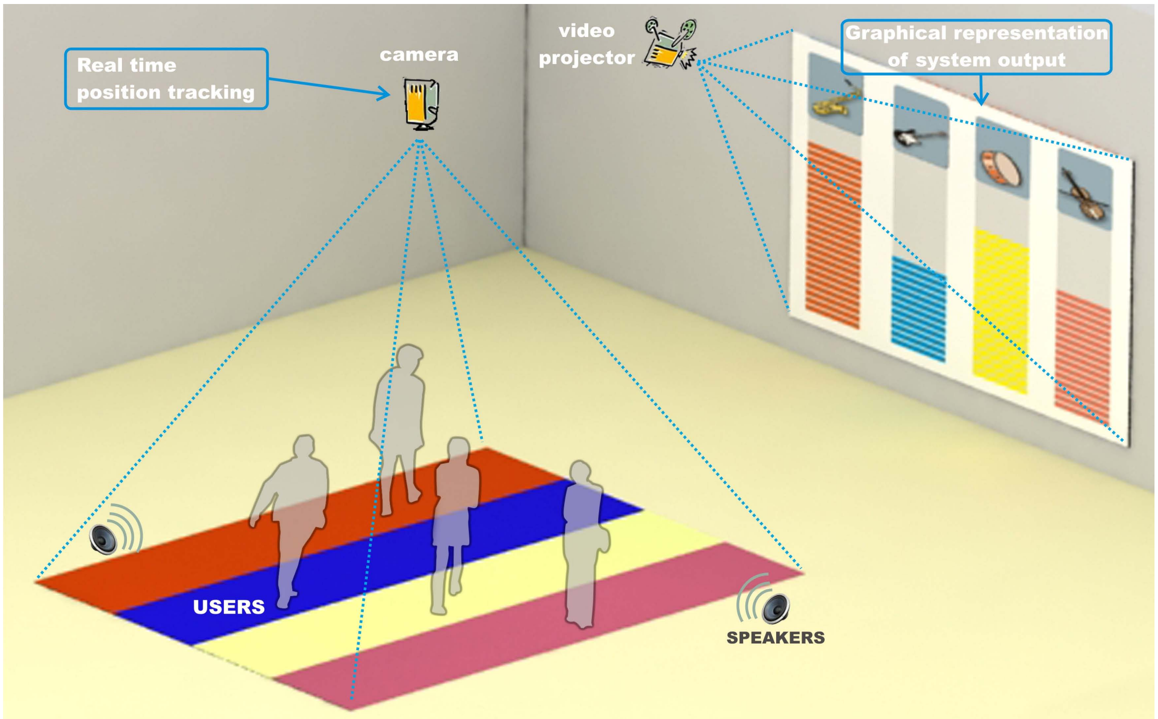


Figure 1: *Four players controlling the dynamics of four independent tracks of instrument music by moving their body*

music track for the Dynamics lesson. The overall system diagram is shown in Figure 5. We compare the difference of the grayscale value of each of the square in the matrix for the current and the previous video frame to detect any person entering that square. In some scenarios where the ceiling height is low and absence of a wide angle camera lens, the person would occupy more than one square in the matrix of the video. We have written a tracking algorithm to comprise the above situations by identifying the square with a higher level and use it to trigger the events in the music lesson. For example in music dynamics lesson, if a person is occupying square 1, 2 and 3. The system will identify the maximum current value to be 3 and use it to trigger the dynamics level of the music.

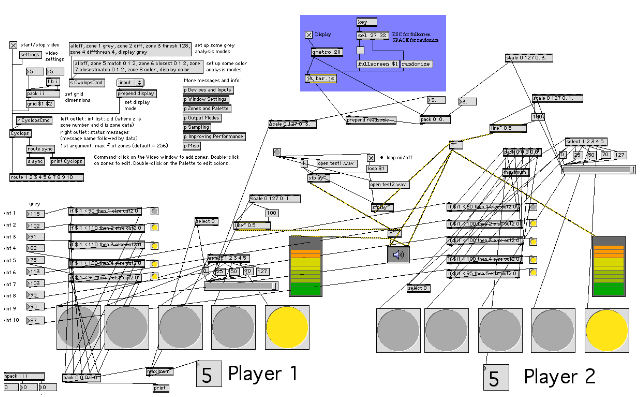


Figure 2: *System developed in MAX/MSP*

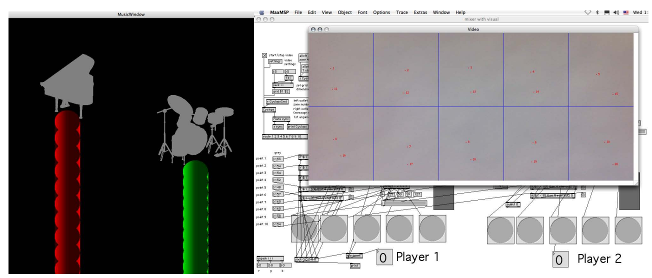


Figure 3: *System in operation: MAX/MSP program on the right and the visual output on the left*

6 Music Lessons

6.1 Frequency

Frequency is related to the number of movements or vibrations per second represented in Hertz (Hz). Another way to describe this is cycles per second. The human ear can perceive the vibrations, which are from 15Hz and 20,000Hz. This means that a string moving back and forth 15 times per second would be audible and would be the lowest pitch. At the other end of the spectrum, at 20,000Hz, the frequency would be the highest pitch and at the upper limit of perception. A string in this case would be moving back and forth 20,000 times per second. The concept of frequency and pitch are normally taught from the perspective of using pianos for pitch and wave diagrams for frequency. While these methods can be useful in teaching the concepts to students, our solution is to provide a mapping of space between two people as the length of a virtual vibrating string. The larger the distance, the lower the frequency and lower pitch. The players see the virtual string on the wall-projected display, which changes in length and vibration speed while the audible

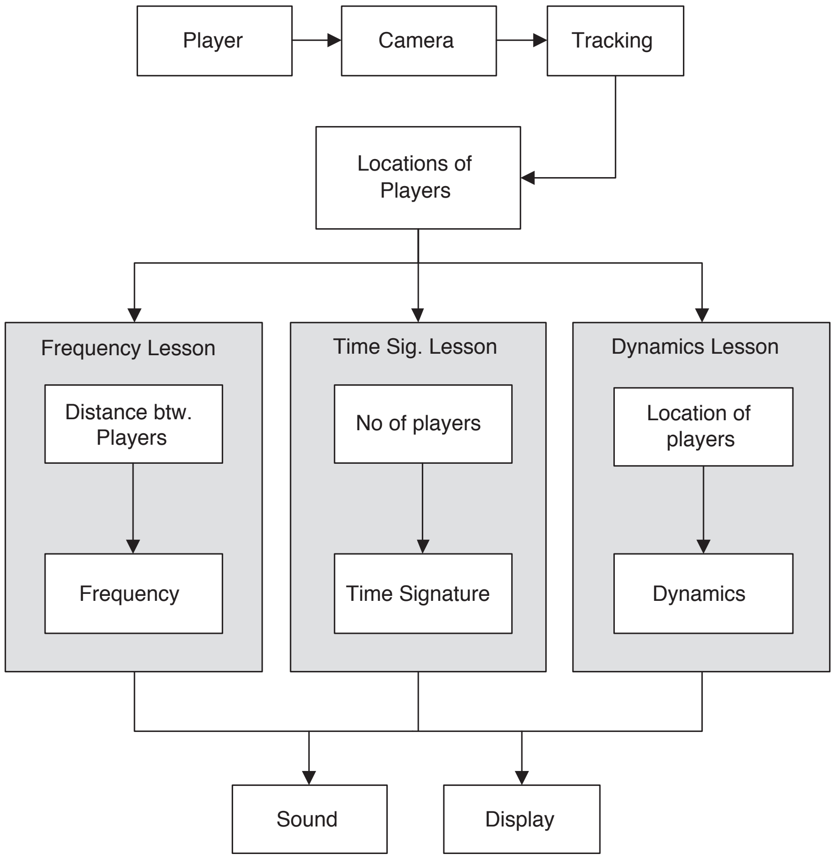


Figure 5: *Overall system diagram*

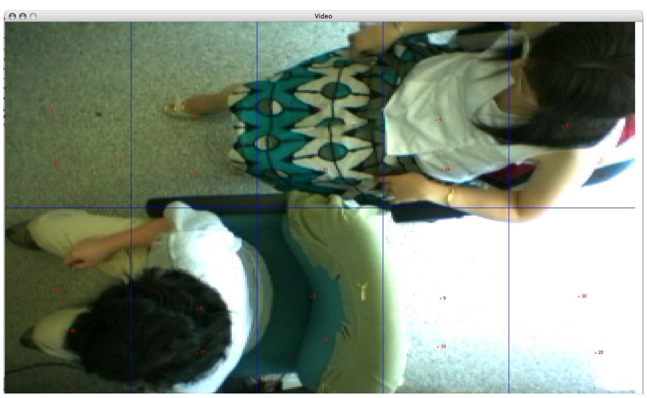
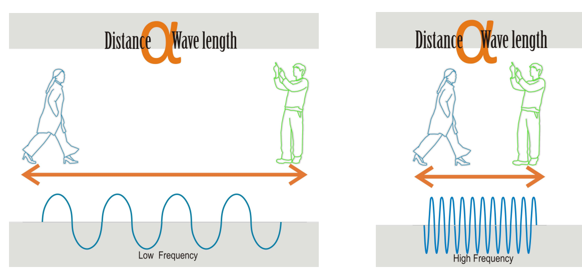


Figure 4: *Camera tracking matrix of 2x5*

sound in the room changes accordingly. To enhance the mapping of the frequency and its translation to instruments, an accompanying animated image of a piano or guitar showing the finger position is displayed along with the numerical frequency in Hz while the corresponding note appears on the staff diagram. While this accomplishes the learning objective of teaching the basic concepts, it goes far beyond and allows for the learner to see the relative range of the various instruments and hear their sounds.

Figure 6(a) shows that when players are standing far apart, they create a lower frequency sound. In Figure 6(b) players standing closer together creates a higher frequency sound.



(a) (b)

Figure 6: *(a) Users standing far apart creates a lower frequency sound (b) Users standing closer together creates a higher frequency sound*

6.2 Time Signature

The concept of basic tempo is often easily understood. With the aid of a metronome, students can hear the clicking sound, which provides a steady division of time and a pace for music. The more challenging concept beyond this is the concept of rhythm and meter. The time signature is most commonly used in Western notation systems to specify how many beats are in each measure and what note value constitutes one beat in the measure. Time signatures indicate meter, but the artist composing a piece of music is free to use another meter, provided that the measures contain the indicated number of beats. Generally, the time signature indicates the feeling of a piece of music. For example, waltzs are always in 3 / 4 time and they give rise to the undulating feel which is most easily expressed in the dance, or by saying outloud, 1,2,3 1,2,3. A change to the 6 / 8 time signature gives the feeling of a very fast waltz and the undulation can be felt by saying out loud, 1, and, 2, and, 3, and, 1, and, 2, and, 3, and. The standard western notation system displays the time signature by placing the beats per measure count above the indication of the note which constitutes one beat. In 3 / 4 time as shown in Figure 7, there are 3 beats per measure and the quarter note is the note which represents a single beat.

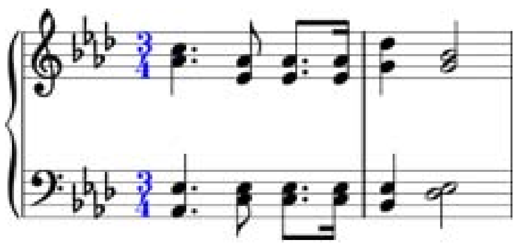


Figure 7: *Standard notation showing the 3 /4 time signature*

In order for the learner to get a grasp for this concept, our learning environment maps the number of players in the space to a particular time signature and plays a melody accordingly. As shown in Figure 8, having three people in the space triggers the melody to play in 3 / 4 time and the corresponding notes being heard are displayed on the projected wall display with each note being highlighted as its corresponding sound is heard. When another player enters the space, the game changes the time signature to the 4 / 4 time and the players can hear the difference, not in speed necessarily, but in the stresses of the notes and the natural cycle of the phrases. This scenario accomplishes the learning objective of demonstrating time signatures in an exploratory way while reinforcing what is heard with what is represented in the notation system.

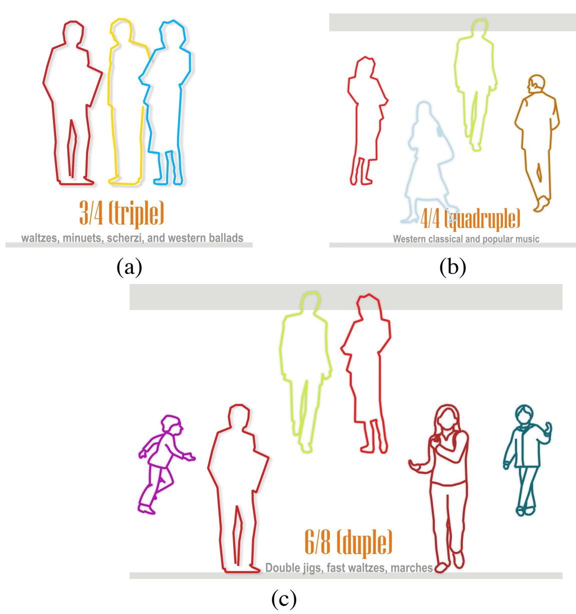


Figure 8: *(a) Three people in the space triggers the melody to play in 3 / 4 time (b) Four people in the space triggers the melody to play in 4 / 4 time (c) Six people in the space triggers the melody to play in 6 / 8 time*

6.3 Dynamics

Dynamics is a musical component associated with volume. In musical terms, dynamics is expressed in notations such as p (piano, soft), mp (mezzo-piano, medium soft), mf (mezzo-forte, medium loud), f (forte, loud), etc. In music CDs and mp3s that we listen to today, rich dynamics conversation between different tracks of instruments in a song are programmed and combined into a stereo track during the mixdown process, hence not allowing players to change the dynamics to their preference.

In order for the learner to get a grasp for this concept, our learning environment maps the position of the player into the dynamic or volume level of a track of music. We have developed a human mixer game to teach music dynamics. Different players in the playground will each control the dynamic level of an instrument track. They move their body toward the screen or away from the screen in order to change the volume level. These changes are reflected on the screen as well. In this way many players can move their body in the playground and controlling the mix of the dynamics of the music they are controlling.

The game play scenario of the human mixer game is shown in the Figure 1. In this scenario, there are four players who each controls a saxophone, guitar, drum or violin music track dynamics level independently. The dynamics level of the music tracks are shown on the projection screen in real time, which correspond to the position of the players. The final output music dynamics is a summation of the collaborative control effort from the players.

7 Evaluation

The evaluation of the learner's progress in serious games in comparison with traditional teaching materials is often difficult to assess [Marsh 2007]. We have seen many methods attempting to show the transfer of knowledge and others, which inform the design using techniques from the entertainment games field [Thompson 2007]. "Figuring out if somebody learned something is a very difficult task" as mentioned by Jonathan Ferguson [Chen and David 2007], Robert Gagne and James Keller [Gunter et al. 2006].

In the context of our game, there may need to be an assortment of evaluation methods made available depending on the context of the game use and the target audience. For example, if the game is situated in a museum setting, it may be that the purpose of the game is to inspire creativity and interest in music theory without a hard and fast score of the student achievement. However, if the game is intended to accompany traditional classroom teaching of music theory, it may be necessary to have a way to show the mastery of the concepts and also demonstration of the ability to transfer the knowledge and skills to another setting. In either scenario, our game requires multiple people to create the interactive experience. This is similar to most music creation, which usually requires the various musical instruments to play their part and to fall together into a synchronized pattern, negotiating the transitions, and playing off of the actions of the others.

Our game is best suited to inspire and allow students to explore as a group and build an understanding of musical concepts and get a taste for "what sounds good" with less focus on the traditional methods of single student testing. One possible way to assess the transfer of knowledge would be for the students to train other students after they have taken part in the game sessions and have mastered the concepts. The trainer students could follow a lesson plan provided to them, but they would also have some freedom to reveal the features of the game in a way of their choosing. This type of "train the trainer" exercise would ensure that the students can transfer the knowledge to others and that they can facilitate the learning session, which can be a delicate balance between story telling and conveyance of factual information. Borrowing from Papert's idea of soft and hard fun, we would like to present and test the knowledge in a way that provides an experience which is a balance between easy experiential rewards and the more lengthy exercises whereas the students build up to an understanding and reward for their efforts. It could be that the "Ah ha" moments of training the trainers could provide this hard fun and give the students a sense of empowerment.

8 User Studies

The refinements to our interactive system were made possible through involvement of users at various stages. These refinements focused on making the learning scenarios more effective, improving the usability of the system, and increasing the motivation or playability of the users interacting with the system. This section describes the refinements made to the system.

8.1 Learning Scenario Refinements

The learning scenarios provide specific lessons about music theory using the physical space in various ways. With play testing of the scenarios with 6 players, we learned that the on-screen feedback of player position and the game state is critical for ensuring that the player understands the connection between their actions and results, but it also gave us insights on improving the effectiveness of the game. The floor was divided into 5 sections for each player for some of the scenarios, these were levels from high to low, or soft to loud, etc. Displaying the activated region and the significance of that activated region on-screen helped to build more meaningful associations to the material. As was expected, the players took pride in pointing out what they believed to be the associated effects of movements and how these translated into changes in the sound. This learning process through group discovery and exploration was reported by the players as being a key feature in the game-based learning process; students would interact, test hypotheses, and then reach a shared conclusion about the interaction and then work to hone their skills as a group in creating sound events.

8.2 Usability Refinements

The interaction space is a large room-sized area which is defined by the field of view of the overhead camera. After the field of view is known, the calibration is then set inside the MAX/MSP program to divide the space into tracks made up of rectangular regions. When the content of any of the regions changes from the background image, it is registered as activated. The human form is fluid and takes up more than one rectangular section at a time. In addition to this, when the players are standing there is the problem of the registration jumping from one to another setting. The players explained that they would lose the sense of connection between their actions and the sounds and animation. This led to awkward moments during the play experience which caused for a break in the flow of the game. We looked at other ways to capture the players including having the players sit in chairs with wheels, rolling back and forth as a way to interact as shown in Figure 9. This made the profile of the human form much bigger, yet it slowed the movement of the players. We added the algorithm which assessed how many regions were considered activated and then of these regions, using the uppermost value as the truly activated region. With this algorithm, the stability of the registration improved the usability because the activated regions became more stable and intuitive for the players. The players expressed that they enjoyed the ability to move around in different ways including the standing and seated positions. Spontaneously, one of the players registered his movements by standing up and moving the chair back and forth with the arms. This showed us that more refinements to the usability can be considered, but that the interactive experience is enjoyable enough that the players actively experiment and seek out the movements that work best for them.

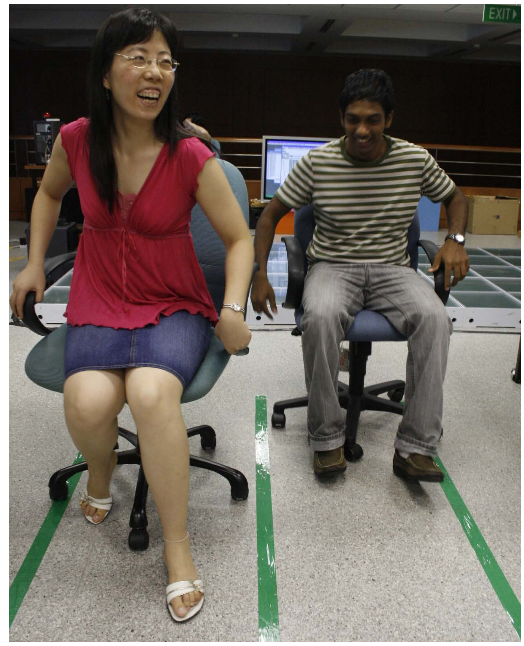


Figure 9: *Players sit in chairs with wheels, rolling back and forth as a way to interact*

8.3 Playability Refinements

In our play testing we quickly noticed that facilitation of the activity was a critical component to the success and understanding by the players. Often, we had to direct the players to move to a specific spot on the floor or to move slowly in order for them to understand the connection between their actions and the sounds being heard. This guided exploration gave the players moments of reflection and activity which is common in other learning activities, but may be more necessary in our larger group oriented scenario. While this type of activity facilitation is possible in a classroom setting, or when directed by a facilitator, if this system is used in a museum setting, we may need to adapt the scenarios to be more user directed and flexible enough to be played with a varied number of users.

Figure 10 shows that the players are having great time playing the game during the user study. The feedback gathered from the play testing confirmed that the system is enjoyable and entertaining, but there were many suggestions for improvements to make the experience even more enjoyable and exciting. One such example was the idea to allow the players to create the sound samples which are used in the scenarios. When this idea was explained by one player, the others became thrilled and excited about the possibility. Another idea from a player involved introducing a timer to the game to give a sense of urgency to the scenarios and to build the excitement. These and other possibilities will be explored in the future prototypes to increase the fun factor of the game based learning system.

Figure 10: *Players enjoying the game during the user study*

9 Discussion

In the following, we discuss the possibilities for future developments of the system including the game mechanics, body based interactions, and concepts for user research.

9.1 Game Mechanics

As described earlier, the driving force in the system is to teach concepts of music. In order to accomplish this, we take the approach that physical, ludic interaction offers a powerful way to engage the players and to teach difficult concepts. By employing the game techniques of cooperation and competition, the users can become immersed in the game experience and share moments of excitement in the social setting. Rules for each scenario need to enhance the experience and excitement, but not detract from the goal of music exploration. There can be a time based system in which the players have to complete the mini-tasks and lessons in order to score points. Additional points can be given for accuracy of the body movements as well. In this way, the style of interaction is similar to DDR, which has been successful in providing enjoyable game play. We are interested in ways in which the game play can be adjusted to individual players, in the shared space so that players of differing skill levels can still enjoy and play together.

9.2 Body Based Interactions

All musical instruments require some degree of physical movement on the part of the musician. In the case of electronic and digital instruments, this is still the case, however there is a much wider range of possibilities when using digital and electrical systems which are not bound to the same rules as traditional physical instruments. We would like to explore expanding the user tracking method to allow another dimension to the game experience. The body movements used when playing the theremin, for example, require the artist to use hand position in order to control volume and pitch. The player of the theremin and our system as well is somewhat bound to the sliding between the range of values and position. It is difficult to create the silent moments in between the notes which is a strength of traditional instruments. We will explore the use of gestures of the players' arms or with handheld switches to allow the players to expand the interaction space. Not only will the location of the player serve as input, but the body gestures can be used to augment or modify the input as is the case with the sustain pedal in a piano, or the foot pedals used by the electric guitarist. The possibilities could include simple electronic switches to add silence or sustain, acceleration sensors for keeping the beat similar to maracas, higher definition camera based tracking for finer position sensing, among others. Another avenue for exploration could be to explore the concept of Eurhythmics, borrow the movements and lessons and together with the technological enhancements, make new forms of body based music.

9.3 User Research

In order to refine the design of new lessons and game scenarios, we will focus on in depth user studies. Our focus will first look at the initial experience and to look for ways in which the player figures out the connection between the movements and the effect on the sound and visual animation. We will also examine each of the scenarios with various age groups of players with various levels of knowledge of music. The system allows for a wide range of game scenarios from the very simple interaction and visuals to more complex scenarios illustrating the physics of sound and therefore, there may be ways in which the system can easily adapt to the user's level of knowledge and provide an appropriately matched experience to increase the amount of enjoyment from the game play.

10 Conclusion

In this paper we present a new paradigm of social musical exploration and creation system using the physical body as an interface. We have created a physical mixed reality interactive game which enables people from all walks of life to interact in a physical space and learn fundamentals of music theory through experimentation. Using large physical body movements, players explored the concepts of music theory as a group with fun interaction. Our system presents to the players a game with mini scenarios each focused on a specific music lesson, with sound events which change according to the movements of the players. The performance and co-creation aspect of the game made the experience exciting and gave rise to unexpected events. The players became very immersed in the experience and not only learned music concepts but enjoyed playing together. One funny event happened when the players were carefully adjusting the volume of the instruments in the dynamics scenario and one player said, "come on drums, you have to step up now!" The other players were laughing at the metaphorical language used and the assumption of roles the player took.

In future prototypes we will look at making advancements in the factors affecting playability and will work to refine the tracking mechanisms to make a tight coupling between natural user movements and the registration of the players. We will also expand the interactive scenarios to include new features as mentioned by the play testers in our search for making fun play opportunities that can facilitate the learning of music theory.

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