3-D POSE PRESENTATION FOR TRAINING APPLICATIONS

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Structured Abstract:

Purpose
In our experience, the biggest issue with pose-based exergames is the difficulty in effectively communicating a 3-dimensional pose to a user to facilitate a thorough understanding for accurate pose replication. This paper examines options for pose presentation.

Design/methodology/approach
We examine 3 methods of presentation and feedback to determine which provides the user with the greatest improvement in performance. We use an on-body sensor network system to measure success rates, and address the challenges and issues that arise throughout the process.

Findings
A 3-dimensional interface allows for full control of the camera, and after conducting all of the experiments, the importance of this feature became exceedingly apparent. Though other elements of feedback were able to illustrate specific problem areas, the camera rotation, improved some success rates by more than double.

Research limitations/implications
Refinements of visual feedback methods during training could include determining the ideal position for the camera to view the avatar after the rotation to maximize pose comprehension. Future research could also include working towards providing the participant with more specific instructions, verbally or symbolically.

Originality/value
In a traditional setting, like a yoga class, a physically present moderator would provide coaching to participants who struggled with pose reproduction. However, for obvious reasons, this cannot be implemented in a computer-based training setting. This research begins to examine what is the necessary user interface for activities that are traditionally very closely monitored.

Keywords: *User Interface, Exergaming, Training, Sensor Networks.*

Research Paper

1. INTRODUCTION

Obesity has fast become one of the leading preventable causes of death plaguing industrialized society, with increasing incidence among adults and children. It is viewed as one of the most serious public health epidemics of the 21st century (Barness et. al, 2007). The physical benefits of leading an active lifestyle are undeniable when combating this disease. Children are especially vulnerable to these diseases due to their increasingly sedentary lifestyles (Berkcovsky et. al, 2009). The success of the Nintendo Wii as a fun way of promoting physical activity among all age groups has sparked an outpouring of more physically active games (or "exergames") being introduced to the market, along with competitor consoles (Hawn, 2009).

With more physically immersive gaming on the rise, new problems with the interface model are introduced – not only is it important to demonstrate what a player must do in a game, but it now becomes equally critical to convey *how* to do it. Regardless of the input type, be it a camera-based system like the Xbox Kinect, or a full-body accelerometer sensor network system (Crampton et. al, 2007), if the game cannot effectively communicate to the player the positions and moves they must perform to control the game, they will have little success.

One issue that has emerged throughout the development of our own exergames relates to the difficulty in training users to replicate unfamiliar full-body poses. Without solving this problem, users tend to not be successful in games and applications that demand accuracy in performance, such as yoga or karate. Communicating full-body pose and motion information is most successful when presented in-person. However, in a typical game and training context, this is not a realistic option. To create a training application for anything from tai-chi, to dancing, it is imperative that we inform the user when they are performing a pose incorrectly, as well as provide them with an interface that specifically communicates *what* they are doing incorrectly. In previous work, it has been shown that providing the user with visual feedback would improve their performance (Johnston(b), 2010); the next step is to determine the most effective type of feedback that could be provided.

In this work, we examine the design problems, and solutions, involved in presenting full-body poses to a player within a training application context. First, we will provide a brief overview of the system. Building upon this, we discuss the move from traditional, 2-dimensional images, to a 3-dimensional avatar for pose presentation. We conduct several experiments to determine the effect of adding camera motion and visual feedback on players' abilities to successfully recreate a given pose, without the help of a moderator/coach being physically present. We also explore different levels of feedback, and what can be considered too much information and thus becomes detrimental to a user's performance. We conclude with a summary of our findings, and a discussion of future work.

2. BACKGROUND

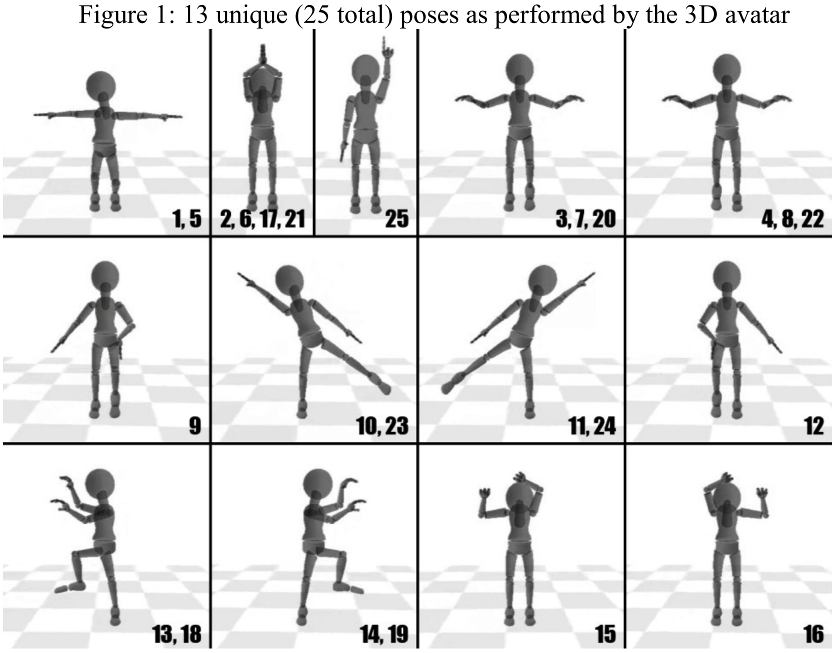
In a game called 'Posemania', which employed a 2-dimensional image-based interface. Photos of people in poses would scroll vertically up the screen and the participants would try to mimic the positions (Whitehead et. al, 2007). For certain poses, particularly those where the front view did not possess the largest cross-section, it was found that providing participants with multiple exposures of the pose, such as side & back views, to illustrate important depth cues was a helpful intervention. (Johnston(b), 2010). Furthermore, it was found that visual feedback also resulted in a higher perceived difficulty because it highlighted minor errors in a body position that the participant otherwise thought to be perfectly accurate. Studies show that roviding a participant with visual feedback slows down their ability to recreate the pose, as they must process more information slowing the visual stimuli response cycle. When pose and motion accuracy is not the ultimate goal in an exergame, less feedback needs to be given. Feedback, however, was found to be a promising strategy when a degree of precision is of greater value than speed, such as in a training application (Johnston(a), 2010).

There is not a lot of academic research available currently on pose and feedback mechanism as there are few systems available that allow significant measurement of the body at interactive rates. There are, however, a few comparable research projects and commercial products. Most closely related is a proposed fitness game for combining motion sensors with arcade-like graphics and gameplay (Buttussi et. al, 2007). The application was controlled through full-body movements replicated by the player. Throughout testing, users who struggled to correctly duplicate the movements requested visual, in-game demonstrations of the motions. The developers introduced a 3D virtual human to demonstrate the movements while audibly encouraging and motivating the user. This avatar would appear when the game engine deemed it necessary based on the user's performance. They found that using a 3D model for the virtual human allowed them to display the exercise from multiple viewpoints, which may have helped improve the understanding of the exercise. They felt, however, that a more thorough evaluation with users would be needed to assess the benefits of the 3D virtual human (Buttusi et. al, 2007).

Charbonneau et al. used their own application called RealDance to explore three different visual interfaces' effectiveness in conveying dance sequence information to players (Charbonneau et. al, 2009). Their three methods of computerized feedback were Motion Lines, Beat Circles, and the Timeline. The motion lines interface showed the player which limbs to move based on the appearance of an icon to represent the limb, and indicated where to move the limb by the motion path the icon followed. The beat circles interface also used an icon placed around the avatar to specify which limbs to move. The position of the icon relative to the avatar signified where to move the limb, and the disappearing circle around the icon indicated when to move the limb. The timeline interface used directional arrows on the icons to indicate where to move the limbs; the icons appeared along a scrolling timeline to indicate when to move the limbs, similar to the type of interface used in games like Dance, Dance Revolution (Konami, 2001). They concluded that spatial interfaces, like the Motion Lines and Beat Circles, were superior visual feedback methods than the traditional Timeline interface for full-body, rhythm dance games. However, it should be noted that the system developed was not accurately measuring pose orientation and were using kinetic cues. The game was also developed with entertainment in mind and not training.

The Sony EyeToy is a system created for the Playstation 2 gaming console system, and Kinetic is a commercial fitness game that uses a virtual trainer to provide suggestions to the user on how to correctly perform exercises (Sony 2010). The trainer is also able to comment on the user's performance, which it tracks using the Sony EyeToy camera system. The game uses limited visual feedback, like shining auras around the onscreen avatar, to indicate proper performance of a sequence of movements. All of these systems focus more on full-body kinetic movement, instead of precise, stationary poses, and only one begins to explore the third dimension with relation to visual feedback and pose demonstration. Other more recent exergame type systems include the Sony PS Move, Microsoft's Kinect system and the extremely popular Wii and Wii-Fit systems. There has been much activity in the development of active game play titles, all of which are engaging the player to be more active during the game play sessions. In all of these systems, the games are still more concerned in detecting that motion or pose has been completed rather than on how well it has been performed.

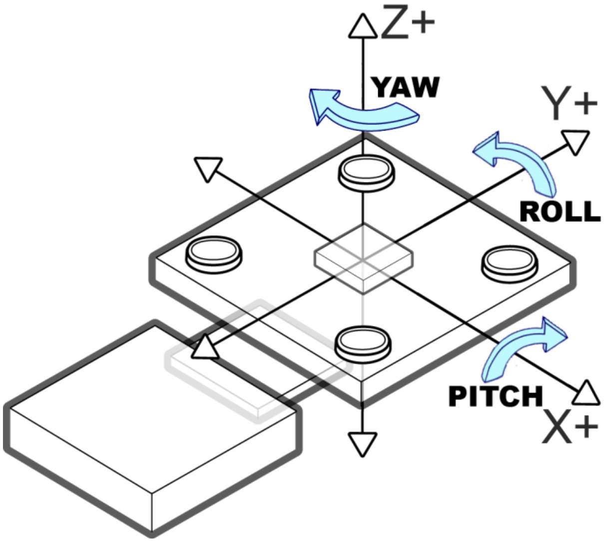
Figure 1: 13 unique (25 total) poses as performed by the 3D avatar



For this work, we used a modified version of a dance-based training application (Whitehead et. al, 2007). This application consists of a 3-dimensional avatar performing a dance on-screen. The player would mimic the avatar and follow along to the music. The dance was comprised of 25 individual poses (13 unique – see Figure 1) inspired by the zombie dance from Michael Jackson's Thriller. This sequence was long enough that the participants would not be able to memorize the order of the poses with only a few run-throughs.

We adapted the software to present the sequence of poses one at a time, without specific timings. Like before, the participant would attempt to mirror the avatar's position. The focus shifted from performing the poses within the correct timing, to recreating the poses with as much accuracy as possible. After the avatar had cycled through all of the poses, the success rate of the participant was calculated and stored.

Figure 2: Axes, Pitch, Roll and Yaw Assignments for tri-axis accelerometer.



3. SENSOR NETWORK SYSTEM OVERVIEW

Within this study, we use an inertial measuring sensor network (Whitehead et. al, 2007) that is attached the arms and legs of the participants. The system records the orientation and position of the limbs to which they are attached and feeds the readings to computer. The system is comprised of a hardware component and a software system.

Figure 3: A covered and uncovered wireless accelerometer with hook and loop elastic bands for attachment to the body.

3.1 Hardware

The SNAP system configuration we used consists of four wireless tri-axis accelerometers (see Figure 2) that communicate with the computer via a small USB stick. Each sensor rests in a custom-made, numbered plastic case and attaches to the body using Velcro and elastic strapping (Figure 3). The sensors transfer data to the application through a server application that runs in the background, collecting all of the raw acceleration values and making them available through a polling scheme.

3.2 Software

For this work, we used a modified version of a dance-based training application (Crampton et. al, 2007). This application consists of a 3-dimensional avatar performing a dance on-screen. The player would mimic the avatar and follow along to the music. The dance was comprised of 25 individual poses (13 unique – see Figure 1) – long enough that the participants would not be able to memorize the order of the poses with only a few run-throughs.

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Briefly, the software for the recognition system is a classical pattern recognition system using the network of information streamed from the sensors (X,Y and Z acceleration values) to compare against a predefined database of pose information. The database is built using a train by example system where the trainers put the sensor network on and engage in the poses while the system records the data. The system is fully described in (Whitehead et. al, 2007).

4. EXPERIMENT DESIGN & IMPLEMENTATION

We define a single test cycle as recreating a sequence of 25 poses presented by an onscreen avatar. The participants would have 10 seconds to recreate each pose presented. If they were able to correctly duplicate the pose, the avatar would advance, and the success is recorded. If they were unable to successfully duplicate the pose in the allotted time, the avatar would still advance. Each participant completed two test cycles. The first run-through was done without computerized feedback. This established a baseline of the participants' skill level among the poses. The second trial was one of four variations explained in more detail in the sections that follow.

We measured the effectiveness of every method using the success rate of each participant, as well as observational results of the person conducting the experiment. We also collected information about the age, gender, height, physical fitness level, and gaming experience of the participants to check for correlations with their success rates.

4.1 Participants

There were 60 participants split evenly among the four different experiments. The participants were all first and second year university students, 63% male, and 37% female. The oldest participant was 34, and the youngest was 17, with 19 as the average age. Data was collected on height, physical fitness level, and gaming experience in the form of a post-trial questionnaire.

4.2 Trial Descriptions

All 60 participants had the exact same initial trial run to establish their individual abilities with each pose, and the interface as a whole. During the first trial run, the majority of participants achieved similar success rates, with few outliers. Three outliers who performed above average attributed their success to how much they play video games in their free time, including full-body systems like the Xbox Kinect, and their strong hand-eye coordination. However, no correlation was found among success rates and overall gaming experience among the participants. More details are presented in Section 4.

4.2.1 No Visual Feedback

The first test variation was used to establish a success rate baseline for participants' skill levels using the 3 dimensional visual interface for comparison with the other methods of visual feedback. It used a static, front-facing camera, and participants were to mirror the avatar's poses. The only computerized indication that the participant was not performing the pose correctly was the avatar not advancing to the next pose.

4.2.2 All-At-Once Visual Feedback

The second test variation was a 3-dimensional equivalent to the feedback previously tested using a 2-dimensional interface (Johnston (a), 2010). It consisted of a stationary, front-facing camera, and an avatar whose limbs would light up red if their sensor's individual error was above the allowable threshold. The brighter the red, the more incorrect that limb's position was.

The "all-at-once" label refers to the idea that all of the sensors that had some kind of error would be coloured red, and thus providing visual feedback, all at the same time. Given that multiple limbs would likely be coloured simultaneously, the participant would have to choose which to correct first, based on which was the brightest shade of red, or try and correct them all at once.

Figure 4: Example displays for each of the trials. (a)Avatar with no visual feedback (trial 1) (b) avatar with all-at-once visual feedback where all erroneous limbs are highlighted (trial 2) (c) avatar with one-at-a-time visual feedback where only the most erroneous limb is highlighted (trial 3) (d&e) avatar front vs. side views taken from a rotating camera around the avatar (trial 4)

(a) (b) (c) (d) (e)

4.2.3 One-At-A-Time Visual Feedback

The third test variation is similar to the all-at-once visual feedback, however instead of all of the limbs providing feedback simultaneously, only the limb with the highest sensor error would be coloured. This allows the participant to focus on one limb, and thus one sensor, at a time. Once the limb has been corrected to where it no longer has the highest sensor error, the new limb with the highest error will become coloured.

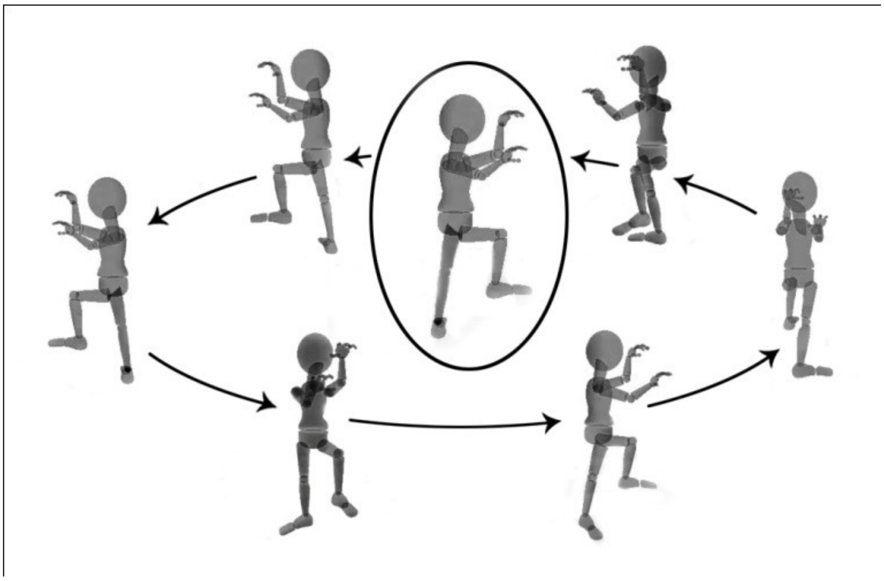
By providing the participants with a more specific focus, it minimizes the excessive body movement that occurs from the participant trying to correct all of the errors at once. It supplies them with a more sequential method to correcting flaws and inaccuracies in pose recreation.

4.2.4 Camera Rotation, One-At-A-Time Visual Feedback

The final test variation uses the same visual feedback as Experiment 3, but with the addition of camera rotation. Previous research suggests that multiple exposures were important to show the full dimensionality of a pose – some positions are best viewed from the side, while others, the front or back Johnston (b) In Figure 2d,e, one can see that the bent knees are almost impossible to distinguish in the front view, but become quite obvious from the side.

In a virtual 3D environment, we have the ability to control the camera, so we can provide a full 360º view of a pose. As a result, however, new problems arise. For a front-facing view, it is most natural and clear for participants to mirror the pose (Whitehead et. al. 2007), however for side and back views, a direct recreation is more coherent. When you add in full rotation, such as in Figure 3, starting with the camera facing the front of the avatar, participants will begin by mirroring it, however once the camera begins to move, they become confused and will start trying to do a direct recreation instead. To avoid this, we start and stop the rotation at a back view instead, so that the participant is no longer required to mirror the pose at any time – they are now to directly mimic the avatar. The camera would complete one full rotation while the avatar is in the pose, starting and stopping at the back-view. Once the rotation was complete, the participant's 10 seconds to correctly replicate the pose began.

Figure 5: 6 views of a pose taken from a rotating camera



5. EXPERIMENT RESULTS

We compared each participant's individual success rates to their basic demographic data, there was no correlation found using Pearson's correlation (Pearson, 1898) between them and any of the questionnaire data (Table 1). This indicates that the successful replication of a pose is more likely reliant on cognitive than physical abilities and characteristics

5.1 No Visual Feedback

As expected, there was minimal improvement between trials when no visual feedback was provided during the second run-through. Though some users did perform better by a few poses, which could be attributed to the act of repetition, others did the same, or worse. The overall pose recognition rate was 15%, though the results varied significantly between individual poses. The improvement was random, with 46% of users showing some form of improvement. A **ρ** value of 0.442 showed the results to be statistically insignificant.

Table 1: Correlation of traits and success rates, 1 or -1 indicates positive or negative correlation, 0 indicates no correlation.

Trait	Pearson Correlation
Age	0.07
Gender Male	0.15
Gender Female	0.18
Height	0.20
Physical Fitness Level	-0.20
General Gaming Experience	0.09
Active Gaming Experience (ex. Nintendo Wii)	-0.01
Full-Body Gaming Experience (ex. Kinect)	-0.04

5.2 All-At-Once Visual Feedback

While there was some improvement seen when all-at-once visual feedback was introduced, the overall results were not consistent across all users. Many found that there was too much information being presented at once, and properly deciphering and processing it took too much time, resulting in confusion. The overall pose recognition rate was 23%, with 65% of participants improving between the first and second trials. The results again were statistically insignificant, with a ρ value of 0.346. Though the colouring helped users identify the problem areas in their pose replication, they had a difficult time deciding which limb to fix first, and would typically start moving their entire body at once.

5.3 One-At-A-Time Visual Feedback

The third experiment yielded more consistent results than the previous experiments, with an an overall recognition rate of 43% and an average improvement rate of 69%. Though the results were not statistically significant, with a ρ value of 0.121, there was still progress over experiment 2. Among the 13 participants for this experiment, only two showed any regression. Unfortunately, since the camera remained stationary, there were still no depth cues as to arm and leg placements in the z-axis, and elements like bent knees went unnoticed. However, the overall understanding of what needed improvement in the participant's pose replication was higher than in experiment 2. The users had a noticeably better comprehension of the visual feedback, and would focus on one limb at a time.

Table 2: Summary of results by experiment

Trial	Average success rate (%)	% of participants who improved performance level	% of participants who improved or maintained performance level	**ρ** values (< 0.05 = statistically significant)
1	15	46	70	0.442
2	23	65	71	0.346
3	43	69	85	0.121
4	54	92	92	0.007

5.4 Camera Rotation, One-At-A-Time Visual Feedback

While there was certainly visible improvement in user performances when colour-coded error indicators were added, there was an even greater jump in results when camera rotation was introduced. The number of participants showing improvement was 92%, with 69% of users improving by 50% or more. The overall success rate among the poses was 54%, and with a ρ value of 0.007, the results were found to be highly statistically significant. The camera rotation made elements like bent knees (see Pose 1 & 5 in Figure 3-2) easily recognizable, and thus resulted in some poses showing substantially high recognition improvement between the two trials.

Table 3: Success rates of individual poses by experiment (%)

Experiment \ Pose	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	15	31	8	0	15	31	23	0	23	8	8	23	31
2	18	24	24	18	29	29	24	12	24	18	24	29	35
3	23	92	8	15	100	100	15	8	23	54	69	38	77
4	69	77	54	8	85	85	31	15	38	69	46	92	85

Experiment \ Pose	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**Avg**
1	8	0	0	23	31	15	8	31	15	0	8	31	**15**
2	24	0	6	29	35	24	24	29	18	18	29	29	**23**
3	8	15	15	77	69	15	23	92	8	31	62	100	**43**
4	0	31	31	85	100	8	46	85	23	77	62	92	**54**

5.5 Comparative Results

When comparing the results from all four experiments with the first trial runs, 100% of the poses showed overall improvement when any form of visual feedback was provided. Table 2 provides a summary of overall results mentioned in the previous sections. Adding camera rotation proved to be a pivotal factor in drastically increasing how many participants were able to improve their scores between their two trial runs. The camera rotation strongly addressed the issue of providing participants with multiple viewpoints of a pose, allowing them to fully grasp all of its intricacies and replicate it to the best of their abilities.

The first column lists the average success rates achieved by each group of participants. The second column shows the percentage of individuals in each group who showed some sort of improvement in their success rate between the first trial with no feedback, and their second trial. The third column shows the percentage of participants in each group who either showed improvement, or remained the same between their two trials. The missing percentages account for those individuals whose success rates were lower for their second trial. The final column lists all of the **ρ** values for the trials.

6 Known Issues and Validity Threats

There are two significant known issues worth discussing. The first is an issue with the training data that was collected to characterize the poses used in the experiment and the other involves representational issues with the avatar pose rendering.

6.1 Training Data Issues

The pose training data used for the experiments was originally recorded by a small sample group of people, and was used primarily by that group only. As a result, the standard deviations in the data set are lower on some poses than others, resulting in some poses that are easier to replicate, and some that are very difficult. The majority of the poses fall within an achievable, yet challenging range for most participants. There was one pose in particular (pose #14/19 – see Figure 1) that proved extremely challenging and nearly impossible for most of the participants to replicate. We included the scores for that pose for completeness sake, however when culled, the recognition and improvement rates increased favourably. Table 3 summarizes the average success rate of each individual pose across all four experiments.

6.2 Avatar Presentation Issues

Another issue that became clear throughout the experimental process was the importance of the avatar's pose clarity to the proper interpretation by a participant. The 3-dimensional avatar was posed independently of the training data, and originally used to indicate which pose to replicate in a game where the users had learned the poses ahead of time. It was not posed for accuracy but as a visual stimulus to elicit a player response. Figure 1 shows the onscreen avatar performing each of the 25 poses. Although it provides a general foundation of pose elements, small nuances, like slight wrist rotations, are lost in the overall positioning. This minimal inaccuracy could be a contributing cause in some of the errors made by participants. It is fundamentally important to provide accuracy in the 3-dimensional renderings of the avatar. A potential fix to this in the future would be to use motion capture technology to capture the exact pose as performed by those in the training set and apply the data directly to the avatar itself.

7. CONCLUSION

We set out to determine the most effective method of providing a user with visual feedback during the training phase in exergames and physical applications like yoga and karate, with the purpose being to replace a physically present moderator coaching the user. We explored some of the design issues that arise when moving from a 2-dimensional to a 3-dimensional interface for pose presentation. We used the new 3D interface to test the influence of camera motion and visual feedback on the users' abilities to successfully recreate a pose displayed on-screen. We also tested varying levels of feedback to determine where it becomes a hindrance instead of a benefit.

Moving from a 2-dimensional to a 3-dimensional pose interface allows for full control of the camera, and after conducting all of the experiments, the importance of this feature became exceedingly apparent. Though other elements of feedback, such as error colour-coding, were able to illustrate the specific problem areas in pose replication, the camera rotation provided participants with a more thorough understanding of the pose prior to the replication process, improving some success rates by more than double. By adding rotation, the "game play" aspect is slowed down significantly, however this shouldn't be an issue when implemented in the training level of a pose-based game. From both the statistical evidence in the success rates, as well as observational evidence conducted by the moderator, it became clear that the participants had a much easier time replicating poses once they'd been provided with a 360º view of the avatar, as opposed to a flat, static, single view of the same character. If given the opportunity to replay the rotation and, in the future, zoom in on more detailed areas of the pose, it can be predicted that the participants' understanding of the poses would increase. It can also be concluded that if the participant were to practice, their success rates would continue to improve to the point of perfecting the poses for real-time replication in games. The results of all of these experiments indicate that when given the proper feedback, participants can significantly improve their success rates in pose-based activities, similar to the results achieved with the presence and coaching of a moderator.

8. DISCUSSION & FUTURE WORK

There are many exergames developed for a variety of different input systems all of which have varying capabilities to measure the players success at completing the scheduled tasks. However, in most games, the emphasis is on engagement and fun as a means to deceive the user into a longer exercise session. Little care is given to the quality in which the participation is conducted. This is to say that current exergames are focused on *what* is getting done rather than on *how* it is getting done. When we become concerned with how the exercises are being performed, it turns out that most of the modern exegame systems are not capable of fully measuring the human body. For example, even the MS Kinect system cannot measure axial rotation that doesn't cause a depth change relative to the camera. As the sensor systems available in the home market become more sophisticated we can expect that the *how* will become significantly more important to exergame developers. As this becomes a more prevalent issue, the interface and communication methods will become very important as well.

In fitness-based applications such a virtual yoga, tai-chi that are inherently pose oriented and have a significant requirement of correct performance by the end user, the user interface will play the primary role in the success of failure of that application. Being able to effectively provide the user information about the quality and correctness of their efforts, as well as providing quality instructional feedback to the user is the next frontier in the exergaming realm as fitness success can be metered more judiciously through better quality human body measuring systems. Over the next years as exergames become more sophisticated, and focus on the *how* over the *what* we will see much more research into the presentation and feedback mechanisms that make up exergames. This works represents some of the first work into this area.

Future work will involve design refinements of visual feedback methods during training. Important topics could include determining the ideal position for the camera to stop around the avatar after the rotation to maximize pose comprehension. This could be taken a step further by providing zoom capabilities on sensor areas that appear to provide the greatest difficulty for the participant. Future research could also include working towards providing the participant with more specific instructions on how to fix problem areas in their pose recreation, verbally or symbolically. All of these elements could contribute towards a training system that is as effective, if not more effective, than one that relies on a coaching moderator.

9. ACKNOWLEDGEMENT

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