# Vibraudio Pose: An Investigation of Non-Visual Feedback Roles for Body Controlled Video Games

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## Abstract

Current video games operate on the assumption of the player continuously facing the screen, which limits the possibilities in full-body gaming. Using commodity game controllers to capture full-body poses, we investigate player performance and experience in 3D video games using positive and negative reinforcement along audio, vibration and visual channels. To explore this, we conducted a study regarding non-visual feedback's effect on participating player's experience and performance. The results indicate that players sometimes performed faster with a visual guide, but preferred visual and non-visual feedback almost equally. Between non-visual feedback types, they performed fastest and preferred audio in a positive role and vibration in a negative role. Additionally, participants preferred vibration to audio as a feedback mechanism.

**CR Categories:** K.8.0 [Personal Computing]: General—Games; H.5.2 [Information Interfaces and Presentation]: User Interfaces—Evaluation/methodology

**Keywords:** vibration feedback, audio feedback, 3D spatial interaction, user evaluation, games

## 1 Objectives

Each year the number of 3D user interfaces for video games increases as these types of control schemes work their way into more mainstream consumer hardware. One significant area that is gaining popularity is games that involve the entire body as an input device. All three of the current leaders in console gaming (Nintendo, Microsoft and Sony) announced new, active gameplay solutions in their systems at E3 2009. However, when a person's full body is the input to the system, it is up to the software to constrain his or her interaction in such a way that conveys instructions clearly and keeps the gameplay fun.

In our previous research on full body input devices for games, we explored different types of visual displays to direct users in how to move their bodies [Charbonneau et al. 2009]. We discovered that some of them had difficulty knowing what to do with visual feedback alone. We received several comments that having a vibration or audio cue could help them understand which body parts they would need to move next. This is particularly true when body movement requires the head to face a direction other than forward, or the user spins or turns, limiting his or her ability to look straight at a visual display.

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Sandbox 2010, Los Angeles, California, July 28 – 29, 2010.
© 2010 ACM 978-1-4503-0097-1/10/0007 $10.00

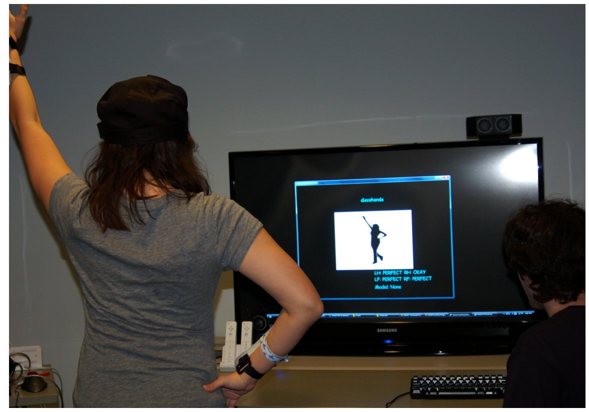

**Figure 1:** *A participant and moderator during a practice session of Vibraudio Pose.*

With this in mind we explored the addition of non-visual feedback in full-body based games. We developed a simple game prototype, Vibraudio Pose (see Figure 1), and an experimental design to test several different feedback options for audio and vibration. This paper discusses our prototype and the results of the formal user evaluation. To aid in the understanding of our research, we define the following terms which will be expanded upon in later sections.

- *Type:* The type of feedback refers to whether it is visual, audio or vibration, sometimes grouped together as visual and non-visual.
- *Role:* The purpose of the feedback in the game, whether it is positive or negative reinforcement. See Section 3.2.2.
- *Conditions:* The experimental tasks were divided into a control Visual Only condition and three non-visual conditions: Positive Only, Negative Only, and Both Positive and Negative. See Section 3.2.4.
- *Mode:* Users were divided into four groups performing different sets of conditions where the type did not change its role, numbered Modes 1-4. See Section 3.2.3.

## 2 Perspective

There is a large body of work in both audio and tactile feedback, much too large to discuss here [Bowman et al. 2004; Salvendy 2005]. Unfortunately, the literature is sparse when it comes to such feedback in 3D user interfaces. There is some work in training methods, such as simulating ballroom dancing using tactile feedback to mimic the lead [Gentry et al. 2003]. Alahakone et. al. has written a review of current uses of vibrotactile feedback in therapy and learning systems [Alahakone and Senanayake 2009].

Several researchers have also compared multiple feedback types against each other. Jerome did an extensive study comparing visual, audio and haptic cues in military simulation [Jerome 2007]. The effectiveness of different levels of force-feedback has been explored with 3D selection tasks [Pawar and Steed 2009]. In mobile computing, there have been studies examining the usability of non-visual feedback [Hoggan et al. 2009]. Researchers have explored wearable devices that use haptic output to communicate with a human user [Spelmezan et al. 2009; Oakley et al. 2006]. However, we found no publications on the effectiveness of different types of feedback in full body motion video games prior to the work in this paper.

Commercially, the video game industry has been using audio and tactile cues for many years, but there are only a few academic papers relating to them, such as analyzing suspense building techniques in horror video games [Perron 2004].

# 3 Methods

## 3.1 Vibraudio Pose Development

The Vibraudio Pose game prototype allows users to learn different body poses. An image of a human in a still position is shown on the screen, and the player tries to mimick the pose. Depending on the game settings, the prototype gives visual, audio, and/or vibration feedback.

Our system is implemented in C#, using Microsoft's XNA, coupled with a 3D user interface framework [Varcholik et al. 2009]. We used four Nintendo Wii remotes (Wiimotes) for both input data and feedback delivery. These Wiimotes were attached to the user's wrists and ankles so that both arms and both legs could be detected and selectively used to provide feedback.

### 3.1.1 Poses

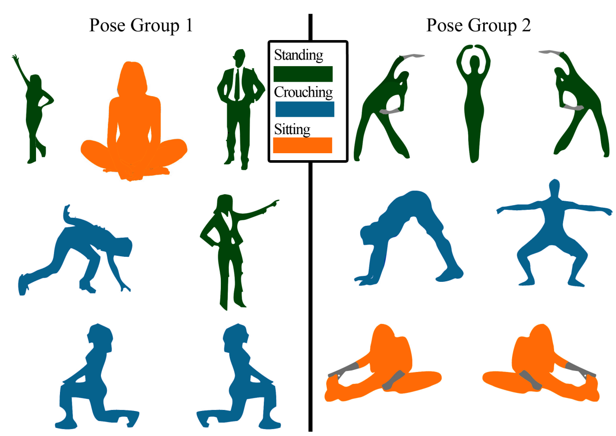


**Figure 2:** *Images used in Vibraudio Pose game prototype, color-coded by the category of the pose: standing, crouching or sitting.*

We used pictures of human silhouettes to show users how to do the required task. These poses were chosen based on how well the training system could define them uniquely, how well participants could distinguish between them, and how well most participants could physically recreate them. Three of the poses were seated, five were crouching and six were standing. The poses were divided into two groups of seven, requiring roughly equivalent skill (See Figure 2). These groups were created as part of our experimental design (See Section 3.2.2) and their difficulty was determined during an initial pilot study.

To train the poses, the principal moderator performed each of them and recorded the average accelerometer data over an eight second interval. During gameplay, the player's accelerometer data is compared to these averages for each limb, producing four scores representing how far they deviated from the training data. Using different thresholds, the scores were grouped into four broader word based scores: PERFECT, GOOD, OKAY and MISS. Our pilot study included participants of both genders and a variety of heights and weights, to ensure robust gameplay.

### 3.1.2 Audio Feedback

Sound has many variables of quality, such as volume and pitch. Because we wanted to limit the complexity of our experiment as much as possible, we limited the sound feedback to a single note at the frequency 3240MHZ from the Wiimote hardware itself. This was played at the maximum volume allowed by the on-board circuitry.

### 3.1.3 Vibration Feedback

Likewise, we chose to keep the vibration variables to a minimum. The Wiimote software we used only has discrete on or off states for the rumble through the controller. For the most part they were similar in intensity, though occasionally a difference in current battery level would make one of the Wiimotes stand out more. This occurred around 15% of the time and did not likely alter results; no participants mentioned this phenomenon on the questionnaire. Also worth noting is that sound is a vibration, and there is a natural audio feedback which accompanies all vibration in our implementation.

### 3.1.4 Per Limb Feedback

Our system delivers non-visual feedback per limb; each arm and leg is receiving information independently. There is a fair amount of confusion between body parts experienced by the average person, when only visual feedback is available. Even if faced with a human figure and told that the figure is mirrored or not, it is likely that the player will become confused. Having a cue from specific limbs was an important part of the game prototype, so that future software implementations could better instruct complex movements.

### 3.1.5 Temporal Variation

Unlike our previous experiments [Charbonneau et al. 2009], Vibraudio Pose does not rely on fixed time intervals for scoring; users are instead challenging themselves to get into the poses as quickly as possible as a measure of skill. Because the timing of the feedback was something that we could modify, we implemented the scoring system so that the feedback would be delivered in timed intervals; for example, if the positive feedback type was audio, it might beep with long pauses if the current score was OKAY, more rapidly when the score became GOOD, and finally, continuously play when the score became PERFECT.

## 3.2 Usability Study

In order to test user performance and experience, we designed a formal usability study. All users played Vibraudio Pose, but the type and role of the feedback was different depending on which mode they played (See Table 1). Since this was an initial study in a new area, we had few expectations regarding the results. However, we developed two hypotheses based on our experience with the pilot study participants:

- H1: Audio would rate poorer than vibration overall, due to its difficulty to detect per limb
- H2: Users would prefer non-visual feedback, despite slower task completion times

| Feedback Types & Conditions | | | | | | |
|---|---|---|---|---|---|---|
| | Audio | Vibration | VisualOnly | PosOnly | NegOnly | Both |
| Mode 1 | Pos | Neg | * | * | * | * |
| Mode 2 | Neg | Pos | * | * | * | * |
| Mode 3 | Pos | Pos | * | * | | |
| Mode 4 | Neg | Neg | * | | * | |

**Table 1:** *The four modes defined by the role each feedback type plays and the conditions experienced by the user. The "*" indicates that condition occurred in that mode.*

#### 3.2.1 Participants and Apparatus

We ran 32 participants (10 female, 22 male) with a mean age of 22 ($\sigma = 3.32$). Almost all of them were students (14 undergraduate, 10 graduate). These participants were found through email mailing lists and fliers around our university. Only 2 expressed issues with hearing audio. Most were avid video game fans with 10 out of 32 playing games several times a week and another 8 playing monthly. The majority also took part in frequent physical activity, with 20 people claiming to exercise several times a week and 27 listing at least one sport or athletic hobby. Two people had back issues which made it difficult to put their hands on the ground; we allowed them the use of a chair to lean on for assistance.

Vibraudio Pose was run on a dual-core desktop PC with an nVidia GeForce 8500 graphics card, using a 50-inch Samsung DLP 3D HDTV display at a refresh rate of 60 Hz. The participants were behind an opaque plastic curtain in a space that was roughly five by five square feet. The moderator operated the program by keyboard controls in front of them (see Figure 1).

#### 3.2.2 Experimental Design

In our experiment, there are three feedback types: visual, audio and vibration. There are four conditions studied: Visual Only, Positive Only, Negative Only, and Both Positive and Negative. This accounts for all permutations of audio and vibration feedback. We do not incorporate the Visual feedback in these iterations because it is our control case when there is no other feedback. Visual was present in all practice rounds but taken away for each play round except for the Visual Only condition. Initially it was thought that having a feedback type for a positive reinforcement and a negative reinforcement was a good idea as this is implemented in some commercial video games (for instance, there might be a rumble when you are hurt and when you receive treasure). However, in Vibraudio Pose, feedback is constant. It is used to continously give an indication of how well the player is doing; each limb is always outputing a score from PERFECT to MISS. In our initial pilot study, using the same feedback type for both positive and negative reinforcement confused participants because it was difficult to distinguish the context without visual reinforcement.

#### 3.2.3 Between Subjects Modes

In addition, participants struggled with remembering the role for each type of feedback. With this in mind, we chose to use a between-subjects approach for cases where the role of a type of feedback changed; for example, the same user never experienced audio as positive and later as negative. We divided our participants into four different groups as shown on the left side of Table 1.

#### 3.2.4 Within Subjects Conditions

These four modes were further broken down into the following conditions: Visual Only, Positive Only, Negative Only, and Both Positive and Negative. See Table 1 for information on which modes contained which conditions. The Visual Only condition was used as a control, while the others were the experimental conditions. Each participant performed all conditions within their mode. For Modes 1 and 2 users experienced four versions of the experimental task with no two participants experiencing the same permutation. In Modes 3 and 4 there were only two conditions because the other two would have been redundant considering the presence of just one role. Half the participants had one first and half had the other first. Using this mixed design experiment, we accounted for all conditions.

| Questions 1-5 | |
|---|---|
| Q1 | The positive reinforcement helped me know when I was doing the right thing. |
| Q2 | The negative reinforcement helped me know when I was doing the wrong thing. |
| Q3 | The game was difficult because I am not used to using my entire body in a video game. |
| Q4 | I had trouble detecting which body part was giving me vibration feedback. |
| Q5 | I had trouble detecting which body part was giving me audio feedback. |
| **Question 6 Variations** | |
| M1 Pos | I felt the audio feedback helped me get into the correct pose. |
| M1 Neg | I felt the vibration feedback helped me know what I was doing wrong. |
| M2 Pos | I felt the vibration feedback helped me get into the correct pose. |
| M2 Neg | I felt the audio feedback helped me know what I was doing wrong. |
| M3 Pos | I felt the vibration and audio feedback helped me get into the correct pose. |
| M4 Neg | I felt the vibration and audio feedback helped me know what I was doing wrong. |
| **Questions 7-14** | |
| Q7 | The nonvisual feedback made the game more fun. |
| Q8 | A system with per-limb vibraudio feedback could help you learn difficult body motions. |
| Q9 | Would you rather know when you are right or when you are wrong? |
| Q10 | Did you prefer the Visual Only mode to the other modes? |
| Q11 | Which type of nonvisual feedback did you like most? |
| Q12 | Which type of nonvisual feedback did you like least? |
| Q13 | Have you ever played any games that used vibration or audio as feedback devices. |
| Q14 | Any additional comments about your experience? |

**Table 2:** *Post Questionnaire. Questions 1-8 used a 7-point Likert scale where 1 indicated Strongly Disagree and 7 indicated Strongly Agree. Question 6 is divided into several similarly worded questions that were different depending on what mode the participant was given. Questions 9-14 were open answer.*

#### 3.2.5 Experimental Task

Each condition was tested using an experimental task with a practice and play round. Each round was made up of seven different poses randomly ordered to prevent learning effects. The participant would receive pose group 1 to do for the first half of the experiment regardless of the order in which they did the within subjects tasks. Again, based on the pilot study, most participants would memorize these poses by the halfway point and so pose group 2 was used for the second half (See Figure 2). The poses were kept independent of the conditions and the groups were roughly equal in difficulty. For each pose, the screen displayed the image of the pose, its name, and a score output for the participant's four limbs: left hand, right hand, left foot and right foot. Between poses, the game paused and the participant was instructed to get into a neutral pose (standing with arms at one's sides). If the correct position was not detected in 30 seconds, the pose timed out.

After the practice round was completed, the play round began. During this round the visual assistance was taken away. In the Visual Only condition, participants still faced forward but were not shown the instructional image for the pose. They had to use the name of the pose and the score output per Wiimote to determine what to do. After fifteen seconds the image would appear to help them.

All other conditions required the user to turn around and face the wall of the enclosed space rather than the monitor. The moderator then read the names of the poses aloud. No further verbal assistance

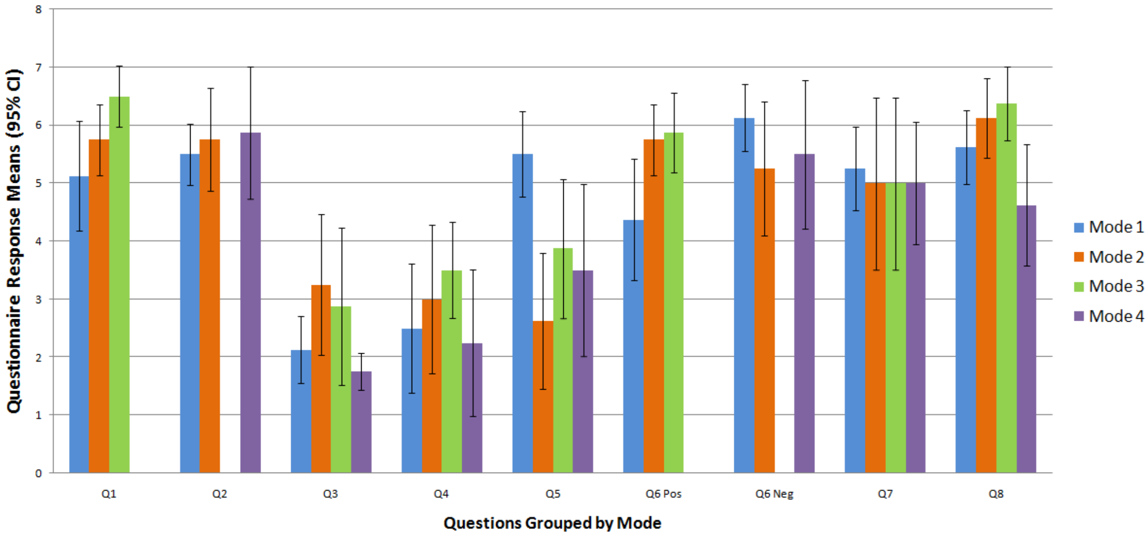


**Figure 3:** *Questionnaire Response Means (seven-point Likert Scale). Q1 regarded positive reinforcement and Q2 regarded negative reinforcement, so modes without those roles were not given that question. For Q6, each mode received a different set of questions specifically for their permutation of feedback type x role. The graph groups the questions by positive and negative for comparison.*

was allowed until fifteen seconds passed, after which the moderator would give the same information as the image (as it was assumed to be a memory problem). We recorded the completion time during the experimental task and had participants fill out a post questionnaire (See Table 2).

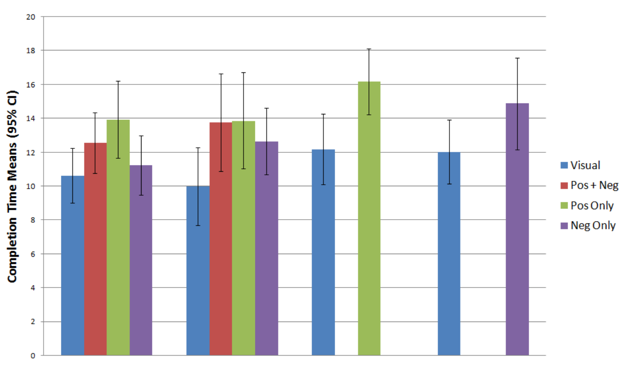


**Figure 4:** *Overall Completion Means*

## 4 Evidence

We analyzed our data across the four modes based on performance and preference. We ran a 2 (Conditions: Visual Only and Both Positive and Negative) by 4 (Mode) repeated measures mixed ANOVA on the average completion times (See Figure 4). For the questionnaire analysis we chose non-parametric testing because the data was ordinal.

### 4.1 Completion Times

We found significance ($F_{1,28} = 21.7, p < 0.05, \eta_p^2 = 0.437, OP = 0.9994$) across feedback conditions. Between modes yielded no significant differences, ($F_{1,28} = 2.31, p = 0.098, \eta_p^2 = 0.20, OP = 0.952$), at the 0.05 level. In addition, we ran a 2 (positive and negative feedback only) by 2 (modes 1 and 2 only) repeated measures mixed ANOVA on completion times and did not find significance for the conditions factor ($F_{1,14} = 0.027, p = 0.873, \eta_p^2 = 0.002, OP = 0.053$) but did find significance for the interaction between feedback and mode ($F_{1,14} = 5.85, p < 0.05, \eta_p^2 = 0.30, OP = 0.614$). The between modes factor was also not significant ($F_{1,14} = 0.159, p = 0.696, \eta_p^2 = 0.011, OP = 0.066$).

Furthermore we conducted analyses using t-tests and controlling for the chance of Type I errors with a Holm's sequential Bonferroni adjustment at $\alpha = 0.05$ [Holm 1979]. We then found significance for the case in which both vibration and audio were on, between mode 1 and mode 3 ($t_{14} = -2.9, p < 0.05, d = -1.55$). When audio was positive and vibration negative, the completion time was much less than when both audio and vibration were positive. Surprisingly, with adjustments, the Visual Only condition was not significantly faster than the Both condition. However, it was close enough that it's possible with more participants it would have been true: for Modes 2 ($t_7 = -3.06, p = 0.018$), 3 ($t_7 = -2.6, p = 0.035$) and 4 ($t_7 = -2.78, p = 0.027$), the Visual Only condition was nearly significant, and in Mode 2 ($t_7 = -4.82, p < 0.0125, d = -1.05$), the Visual Only condition was significantly faster than the Positive Only condition.

This was surprising since, from observations, participants seemed to be faster in Visual Only; however this fact supports the merit of non-visual feedback. It is also worth noting that Mode 1 is the only mode which was clearly not significant when compared to Visual Only results ($t_7 = -1.24, p = 0.26$). This indicates that of non-visual feedback modes, Positive Audio and Negative Vibration was the fastest. It also indicates the Negative Only condition is comparable in speed to Visual Only, regardless of how feedback was assigned to the roles.

### 4.2 Questionnaire Data

We ran Kruskal-Wallis tests on the participants' questionnaire data, which identified significance in audio detection per limb ($\chi_3^2 = 9.1, p < 0.05$) and using vibraudio feedback ($\chi_3^2 = 8.864, p < 0.05$). Using Mann-Whitney tests, we found that more people had trouble detecting audio coming from each Wiimote in Mode 1 than in Mode 2 ($Z = -2.79, p < 0.05$). Perhaps because of the greater need to know per limb data when negative, the participants noticed the audio better.

Also, using a Mann-Whitney test, we found that more people thought the system would be better for learning in Mode 2 ($Z = -2.26, p < 0.05$) and 3 ($Z = -2.44, p < 0.05$) in comparison to Mode 4. This seems to imply that having no positive feedback at all made it hard for them to learn, but that positive feedback that was audio only was almost as bad. This seems much different from the score results, which indicated Mode 1 had the better completion times.

## 5 Substantial Conclusions

Our results confirmed our initial hypotheses to varying degrees. The completion times shows that having only visual feedback is faster for most people. The questionnaire data lead to many other interesting trends, discussed below, which support that vibration was preferred over audio. In addition, it seems that most people are evenly distributed between preferring Visual Only or non-visual feedback, except for Mode 1.

### 5.1 Histogram Data

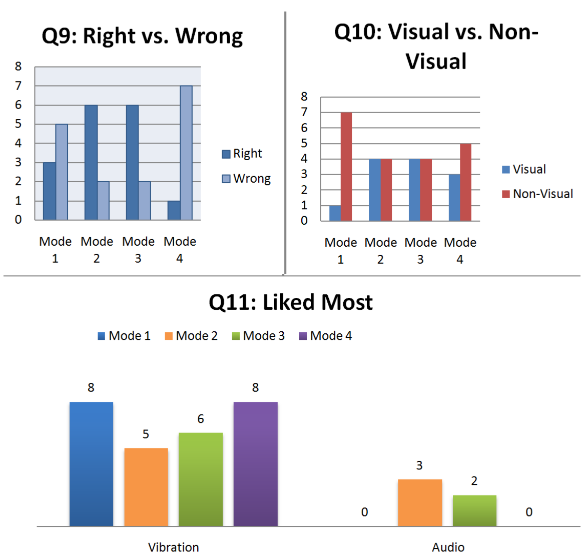


**Figure 5:** *Histograms of Questionnaire Data*

Aside from the statistically significant results, we created Figure 5 to show how some of the other questionnaire data implies other connections. Users were asked whether they preferred to be told when they were right, or when they were wrong. The majority of the time, users chose whichever condition vibration was used in, especially in Mode 4. Also, all but five participants preferred vibration to audio. This seems to imply that vibration makes more of an impact on their experiences. Additionally, across Modes 2, 3, and 4, half of the participants preferred Visual Only and half did not. But in Mode 1, only one person out of eight preferred Visual Only. This indicates that participants seem to enjoy positive audio, negative vibration more than others. Games using non-visual feedback should consider this setup for the most enjoyable experience.

### 5.2 Write In Questions

*Did you prefer the Visual Only mode to the other modes?* Those who preferred Visual Only mainly said it was faster or easier, with a couple focusing on the fact that they could not remember without having a picture in front of them. If they preferred non-visual, the reasons most often given were that it was more fun, more unique, or more challenging. However several people thought it was the easier method.

*Which type of non-visual feedback did you like the most?* Very few people preferred audio, but when it was liked best it was due to familiarity or ease of use. The vast majority of participants liked vibration because they felt it was simpler to detect, more comfortable to feel, and easier to distinguish spatially.

*Which type of non-visual feedback did you like the least?* Three out of the five who disliked vibration said it was hard to tell what was vibrating. Since most people did not have that problem, it could be that some people are less sensitive to vibration feedback. Those who disliked audio stated most often that it was hard to distinguish per limb, which we expected. But what was interesting is that this came up much more often when audio was used in the positive role; it was present ten times compared to three. When audio was used in a negative role, it was considered annoying or distracting by six people, but nobody given audio in the positive role complained about it in this way.

### 5.3 Memory Recall

One of our concerns in doing this experiment was that users' data would be influenced by their ability to recall the poses beforehand. During the pilot study, participants sometimes remembered the next pose in the sequence from the practice round; they would already be in position and receive much faster scores. Because of this we enforced the neutral pose and organized the poses into two distinct sets.

However, there were many participants who seemed frustrated by the memory issue and in fact focused on that more than on the feedback from the system. Prior to the experiment, they were told that each pose would have a name for later recall, and during the play round they were reminded to use the feedback to assist them. Some still had trouble, but the experiment was designed to test whether the feedback could help a person into different physical positions without the need to remember them.

### 5.4 3DUI hardware

It is also worth noting how our physical implementation might have altered the results. The Wiimote was able to do everything necessary for this project, but it is bulky as a worn device because of its multiple buttons and infrared camera. Ideally a smaller wireless device capable of audio and tactile feedback and accelerometer input would improve our prototype.

## 6 Scientific Significance

There are several ways that this research could be extended in the future. Ignored in these experiments is how vibraudio feedback can be used as a cue for movement. Testing the effectiveness of the feedback as a cue prior to movement is a logical idea given our previous experiment as well as some related work we have encountered [Jerome 2007].

Our findings could also be improved by moving beyond the limitations of our experiment. In retrospect, while significant statistics were found, the relative power of them could have been reinforced by a larger sample size of participants. Considering this is our initial study in the subject matter, we can research more specific feedback conditions in the future. We did not have precise control of the vibration feedback using the Wiimotes; a different type of hardware might have suited our needs better. The duration or intensity of the vibration could be altered in a new experiment. For audio, many options are possible, as different sounds can denote a positive or negative connotation. Most notably, the suggestion by participants that we use a different sound for each limb is a direction worth exploring. A more rigorous exploration of pose difficulty would allow future studies to specialize their focus on feedback performance. And the use of studies relying on human memory would have been helpful given most participants concerns about remembering the poses rather than trusting the feedback to guide them.

In games utilizing the entire body as an input device, the near limitless ways in which the player can move implies that the user is not always going to be looking at a visual display, and even so may be confused by what he or she is asked to do. In this work, we have shown that using audio and tactile feedback is just as valid a technique as visual feedback, and in some cases provides additional benefits. Participants seemed to perform comparably between nonvisual in the Negative Only and Visual Only conditions. Users preferred vibration to audio and implicitly preferred feedback roles when they were utilizing vibration. Between modes, they preferred and performed best when audio was positive and vibration was negative. These results present the benefits of non-visual feedback in full-body interfaces.

## 7 Acknowledgements

This work is supported in part by NSF CAREER award IIS-0845921 and NSF Awards IIS-0856045 and IIP-0750551. We wish to thank the anonymous reviewers for their valuable suggestions.

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