Influence of Real-World Ten-Pin Bowling Experience on Performance during First-Time Nintendo Wii Bowling Practice

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Abstract. In order to understand if proficiency in a real-world activity influences performance or movement characteristics in a simulation of that activity, six expert real-world ten-pin bowlers, ten novice real-world ten-pin bowlers and eight expert Wii bowlers completed 3 games of Nintendo Wii Sports' bowling game. Two values were recorded for each throw: the (score) and the total range of motion (ROM) for the participant's throwing arm (using two-dimensional motion capture). Averages across the first five trials were compared to averages across the last five trials. From the first five to last five trials, there were significant increases in both the mean score and mean ROM values, when collapsing data across experience level. While there was a significant main effect of experience level on the overall ROM values, differences between each experience group's ROM values were not detected. A larger sample size is necessary to confirm if real-world ten-pin bowling experience influences score and ROM during first-time Wii bowling.

Keywords: Motor program, motor learning, motion capture, gesture-based interaction, video games, transfer of skill, real-world vs. simulation.

1 Introduction

When it was launched in the U.S. in late 2006, the Nintendo Wii video game system gained much interest from gamers and human factors professionals alike due to its unique input device. This device, called the Wii Remote, is a wireless handheld controller (see Fig. 1.) with sophisticated motion tracking technology that utilizes accelerometers, infrared sensors and Bluetooth technology [1]. Players use the Wii Remote to simulate in-game movements in order to accomplish a task. By holding the Wii Remote in different positions and producing different hand and arm gestures, a player can simulate a myriad of situations, such as steering a car, playing a guitar, punching an opponent, and wielding a lightsaber.

Nintendo has marketed the Wii as a gaming system accessible to all who try it, regardless of age or skill level. However, when first released, it was unclear how easy it would be for novice users to succeed when using the gesture-based Wii Remote to play games. Also unclear was the extent to which prior experience in a real-world

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activity would impact performance or the arm movements used when simulating that same activity using the Nintendo Wii.

Nintendo's *Wii Sports* bowling game was chosen as the primary stimulus because it is closely modeled after the rules of the real-world game of ten-pin bowling and the outcome is wholly dependent on user input. Novice and expert ten-pin bowlers participated in the current study, as well as a control group of expert Wii bowlers. Performance was measured using the score of the first throw. The total range of motion (ROM) of the dominant bowling arm during the first throw was measured using a two-dimensional motion capture system.

The primary goal of this exploratory study was to clarify the relationship between experience with a real-world activity, performance simulating the real-world activity, and arm movements used to simulate the real-world activity. Specifically, the study examined if either group's score or ROM values changed during a first time Wii bowling practice period.

2 Background

2.1 Ten-Pin Bowling

In the modern American sport of ten-pin bowling, players score points by rolling a weighted ball down a lane and knocking over pins. While real-world bowling technique varies from athlete to athlete, most players use a similar arm swing movement and a four- or five-step approach technique. In one throw, a bowler receives kinesthetic, visual, and auditory feedback. Based on the outcome of a delivery, the bowler can choose to use the same movement or modify the movement in the next frame [2].

In ten-pin bowling, repetition is key. The more precisely a bowler can duplicate the same series of motions each time they throw the ball, the higher his or her score will be. It can take years to master proper bowling technique with consistent precision and accuracy. While the amount of time and experience needed to become an advanced bowler varies, technique is likely to be fairly consistent and well established once a bowler reaches this level.

2.2 Nintendo's *Wii Sports* Bowling Game

The *Wii Sports* video game, which is a part of every Wii console, includes a bowling game. The game (see Fig. 1) uses the same rules and scoring conventions as real-world ten-pin bowling and the virtual environment is modeled after the environment and playing area seen at a real bowling alley.

In *Wii Sports* bowling, players hold the remote and move their arm like they would in the real-world game of ten-pin bowling. When a player is ready to roll the ball, he or she holds down the trigger button located near their index finger and then raises the remote to their chest. While holding down the trigger button, the player swings as if he or she was rolling a real bowling ball [3]. When the player is ready to release the ball, he or she releases the trigger button at the bottom of their swing.

Fig. 1. The Nintendo Wii Remote video game controller (left) and a screen view of Nintendo's Wii Sports bowling game (right)

2.3 Motor Schema Theory and Transfer of Skill

Over time, a real-world bowler learns the series of body motions necessary to produce high scores. Schmidt's motor schema theory attempts to explain how motor skills, such as those used to develop proper bowling technique, are generally learned [4]. Learning motor skills involves acquiring schemata which define the "relationships of the information involved in the production and evaluation of motor responses" [5]. These rules are learned through experience and used by the motor programs to produce new actions [6]. Schema theory describes an overall mental construct, a "generalized motor program", which uses the schemata to determine specific actions. For example, over time, a bowler generates a 'bowling motor program'.

Motor learning is the process of improving motor skills where one utilizes a "set of processes that underlie the changes in a capability for movement" [5]. During the process of motor learning, a person's motor movements will change as they develop the internal capability for the movement. While motor learning can be neither directly observed nor defined as a change in behavior, the processes taken together will lead to some particular product, state or change. One can infer the presence of motor learning based on the observed changes in motor behavior over time. When a bowler's approach starts producing consistent results, they have learned what movements are necessary for their expert bowling motor program.

If the tasks of throwing a ball in real-world bowling and Wii bowling are similar enough, skill may be easily transferred. The amount of transfer of skill between two similar tasks depends on the degree of similarity of the two tasks. As the tasks become more dissimilar, the amount of transfer, as measured by performance, can be expected to decrease [7].

It has yet to be determined whether a purely quantitative relationship exists between the degree of task similarity and subsequent change in the amount of transfer. According to the motor schema theory, if a task is modified in some way and this similar-yet-modified task is practiced routinely for a non-trivial length of time, it is possible that a separate motor program will eventually be created.

When tasks are practiced in simulations prior to being actually performed, a positive transfer of skill has been consistently observed in previous studies [8, 9]. Unfortunately, little research has been done on human performance when skills are transferred from a real task environment to a virtual environment. However, there is some evidence that this transfer of skill can be positive in certain applications [8, 10].

3 Experimental Goal and Hypotheses

When a user is first exposed to a system, they choose a technique based on prior knowledge and motor schemas associated with the task requirements. Therefore, when players are told that a video game is a bowling simulation, they may assume the two activities to be similar and start the video game with a similar movement technique to one they have used for real bowling.

While proper real-world bowling technique has been documented, proper (i.e., most effective) Wii bowling technique has yet to be determined. The nature of the Wii bowling simulation is such that it does not give users adequate kinesthetic feedback from the heavy ball. Players may start out using their general bowling motor program, but with practice, may modify their schema and arm movement behavior for Wii bowling. With experience, Wii bowlers may develop a modified arm swing movement that does not require the transfer of momentum to the ball from the full arm swing motion, but still achieves the goal of knocking down pins. Though it may be largely based on the original generalized motor program, another modified program may develop over time.

Given the aforementioned topics, questions begin to arise. When expert real-world bowlers play Nintendo's *Wii Sports* bowling game for the first time, does their proficiency at the real task help or hurt their performance at the simulated task compared to novice bowlers? Will either groups' movement characteristics or performance abilities change during their first bowling session and, if so, how? How do each group's movement characteristics and performance abilities compare to expert players of Nintendo's *Wii Sports* bowling video game?

The present study was developed in an attempt to examine these questions by observing the movement characteristics and performance abilities of novice and expert real-world bowlers over one experimental period of Wii bowling. Because they both had limited experience with the Wii bowling game, the expert real-world bowlers and novice real-world bowlers were expected to start the study with similar ROM and scores. However, because they would not be limited by the real-world bowling motor program, the novice real-world bowlers were expected to have a greater decrease in ROM and greater increase in score compared to the expert real-world bowlers. Therefore, the novice bowlers would end the experimental period with a smaller ROM and higher score than the expert real-world bowlers. As the control group, the expert Wii bowlers were expected to show no change in ROM or score over the experimental period. Their ROM was expected to be the smallest and their scores were expected to be the highest of the three groups.

4 Methodology

4.1 Participants

A sampling method of convenience was used to recruit three groups of participants: Expert real-world bowlers, novice real-world bowlers, and expert Wii bowlers. Table 1 shows a summary of the participant characteristics.

Table 1. Summary of group characteristics

Group	Real-world bowling experience		Wii bowling experience	
	Mean score per game	Frequency of playing	Mean score per game	Frequency of playing
Expert real-world bowlers (n=6)	> 160	≥ 1x/week	< 100	< 2x/month
Novice bowlers (n=10)	< 100	< 2x/month	< 100	< 2x/month
Expert Wii bowlers (n=8)	NA	NA	>160	≥ 3x/month

The group of expert Wii bowlers was used as a control group. The data collected from this group was treated as a baseline comparison for the data collected from the other two groups. The real-world ten-pin bowling experience from this control group was not taken into consideration, as their Wii bowling technique (i.e., a unique schema) has already been established regardless of their ten-pin bowling experience.

4.2 Procedure

The experimental tasks were performed on the Nintendo Wii. Participants used the Wii Remote to interface with the video game system. Participants were given a 6 ½ foot by 3 foot playing area within which to move. This allowed them to play the game with free and natural movement while allowing us to record their movements.

Two reflective markers for the motion capture system were attached to Velcro strips and placed around participants' right humerus. The approximate length of the participant's humerus was measured and the two strips were placed at the first and third quartiles of the upper arm (see Fig. 2). Participants were then given a short orientation to become familiar with the Nintendo Wii interface and control of the Wii Remote within the Wii bowling game.

Regardless of group assignment, all participants performed the same experimental task. They were asked to play the Wii bowling game with the goal of achieving the highest score. Participants completed three games of ten frames each, for a total of 30 trials. A trial was defined as a full frame which may have included a second throw, as per standard ten-pin bowling rules. Participants were required to stand during the trials and allowed to walk and lean forward as long as they stayed within the designated area needed for the motion capture system to function properly.

4.3 Data Collection

Two values were recorded for each throw: the number of pins knocked over (score) and the total range of motion (ROM) for the participant's arm. The arm movement was recorded with a motion capture video system and later translated into a ROM value represented as an angle.

Motion capture is the process of digitally recording body movements and translating them into a two- or three-dimensional model [11]. A 2D motion-capture video system was used in this study. The system consisted of a digital video camera, passive reflective markers placed on a participant's upper right arm, a light source pointed at the participant (to increase the amount of light reflected by the markers), and a computer running the digital video capture and Peak Motus software package [12]. The camera faced participants laterally and recorded the projection of each reflective marker at 60 frames per second. Accounting for the position and orientation of the camera, the software used the digitized video to transform these projections into a 2D position of each marker. The motion capture system was configured to allow for the capture of the entire arm swing motion of each throw.

4.4 Data Analysis

In a game of real-world bowling, the goal of the first throw in a frame is always the same: knock over as many pins as possible. The conditions during the second throw of a frame are highly variable and entirely dependent on the result of the first throw. Therefore, our primary analysis focused only on the data collected during that first throw. However, participants were asked to complete both throws of every frame.

A statistical analysis of the score data was conducted for all three participant groups. Since the change in performance over the experimental period was the primary variable of interest, the scores of the first throws from the first five and last five trials were included in the analysis.

In order to calculate the ROM joint angles, the digital video data needed to be digitized by the motion capture software [12]. In this process, for each first throw, the software located the position of the centroid of each reflective marker from each frame of the video such that the participants' arm motion was converted to a series of x-y coordinates. Maximum amount of shoulder flexion and hyperextension were deduced and combined to create the total ROM for each swing. Similar to the performance score analysis, only ROM data from the first throws of the first five and last five trials were analyzed for each participant group.

5 Results

5.1 Wii Bowling Score

A 2 x 3 (trial period by experience level) split plot Analysis of Variance (ANOVA) was conducted on the score data where trial period (first five trials and last five trials) was the within-subjects variable and experience level (expert real-world bowlers, novice real-world bowlers and expert Wii bowlers) was the between-subjects variable. The purpose of this analysis was to determine if experience level influenced how much a participant's score increased from the first five trials to the last five trials. A paired t-test was also conducted on the mean scores of the first and last five trials for each group. Figure 2 shows the average score for each group during the first five and last five trials.

The main effect of trial period was found to be significant ($F_{1, 21} = 4.89$, $p < .05$). Overall, the scores from the last five trials (M = 8.23) were significantly higher than the scores from the first five trials (M = 7.83). There was no main effect found for experience level. This means that overall no one group scored better than another

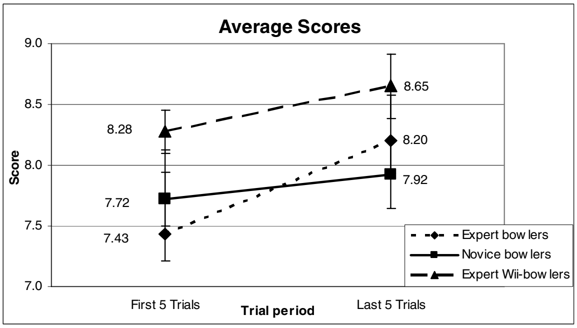

Fig. 2. Average scores of each group for the first and last five trials of the session

group. Furthermore, we found no interaction between the trial period and experience level. From the first five to last five trials, no one group's scores increased significantly more than the other groups' scores.

5.2 Range of Motion

A 2 x 3 (trial period by experience level) split plot ANOVA was conducted on the ROM data where trial period (first five trials and last five trials) was the within-subjects variable and experience level (expert real-world bowlers, novice real-world bowlers and expert Wii bowlers) was the between-subjects variable. Similar to the score data, the purpose of this analysis was to determine if experience level influenced how much a participant's ROM changed between the first five trials and the last five trials. Figure 3 shows the mean ROM for each group during the first five and last five trials.

The ROM results show a significant main effect of trial period ($F_{1, 21} = 17.43$, $p < .001$). Overall, participants' ROM increased significantly from the first five trials (M = 157.76°) to the last five trials (M = 180.19°). Post-hoc t-tests showed a significant increase in ROM for the expert real-world bowlers, ($t_5 = 3.094$, $p < .05$) and novice bowlers ($t_9 = 4.19$, $p < .005$) but not for the expert Wii bowlers.

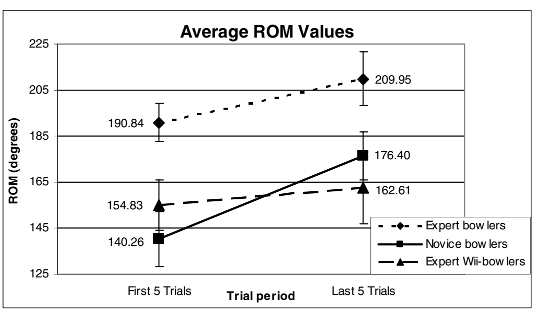

Fig. 3. Average ROM values of each group for the first and last five trials of the session

There was also a significant main effect of experience level ($F_{2, 21} = 3.89$, $p < .05$). Post hoc comparisons showed no significant differences between the individual experience levels, although there was a non-significant trend for expert real-world bowlers to have a larger ROM than novices ($p = .055$) and expert Wii bowlers ($p = .074$). The results also revealed no interaction between the trial period and experience level. This means that the three groups did not differ in the amount of ROM increase.

5.3 Correlation

The Pearson product-moment correlation coefficient was calculated between the score and ROM variables to determine if there was a relationship between the increase in ROM values and the increase in score. This analysis did not reveal a significant correlation between the mean ROM and mean scores. There were also no significant correlations between the mean ROM and mean scores for each individual group.

6 Discussion

The purpose of this study was to determine if proficiency in ten-pin bowling influenced performance abilities or movement characteristics when playing simulated Wii bowling. In general, the data did not support the original hypotheses that novice real-world bowlers would have a greater decrease in ROM and greater increase in score than the expert real-world bowlers. In several cases, test statistics approached significance, suggesting that the lack of support for some hypotheses may be at least partially due to the small number of observations analyzed in this study.

6.1 Wii Bowling Score

While the overall Wii bowling scores increased significantly from the first five to the last five trials, there was no significant main effect for experience level nor was there a significant interaction between experience level and trial period. These findings indicate that novice real-world bowlers did not have a greater increase in score than expert real-world bowlers. An observed range effect may have prevented the detection of a relationship between experience level, trial period and Wii-bowling scores. While ten-pin bowling scores can range from 0-10 pins per trial, participants' average scores only ranged from 7.43 to 8.65.

6.2 Range of Motion

The significant increase in ROM during the session is contrary to the original hypothesis. The training period for this study only included one frame of Wii bowling. It is possible that participant's bodies were not fully warmed up when they started their first trial and the overall increase in ROM was related to the loosening of their joints and increased activity of their muscles.

The fact that the expert real-world bowlers had the largest overall mean ROM suggests these participants may have applied their established real-world bowling motor program to play Wii bowling, which requires a large arm swing movement to propel the weighted ball down the lane. The significant increase in ROM for these participants can then be explained by the warm-up theory described above.

The novice bowlers should not have such developed real-world bowling motor programs. However, the expert real-world bowlers maintained a bowling motor program for a reason: they were experts at real-world bowling. The non-significant trend for novice bowlers to have a smaller ROM than the expert real-world bowlers may be a result of novice bowlers not having a real world bowling motor program to define how large of a movement to use during Wii bowling.

The significant main effect of experience level on ROM points toward a confirmation of Schmidt's motor schema theory and the existence of generalized motor programs [4]. With a larger sample size, it may have been possible to determine if experience in real-world bowling influenced the increase in ROM over the experimental period.

6.3 Correlation

While the ROM data was collected for this study using a 2D motion capture system, real-world and Wii bowling can involve 3D arm and body movements. For example, many expert real-world bowlers twist their wrist right before releasing the ball to include a spin. No correlation between ROM and score data was discovered. A likely explanation for the lack of correlation between ROM and score data is that data collection was solely focused on the 2D arm swing movement at the shoulder. The influence of any other body part and the overall body motion in all three dimensions was ignored.

Additionally, as discussed before, the increase in ROM may not be related directly to the score performance because participants' bodies may have been warming up throughout the thirty trials. As the joints were loosened and the muscle activity increased, the ROM at the shoulder may have increased because their arm muscles were able to stretch further. This may be another reason why no correlation was found between the overall mean ROM and overall score.

7 Conclusion

Based on the overall increase in score, participants playing Wii bowling for the first time were able to improve their performance in just three games. These results indicate that the Wii bowling game was designed to allow for quick improvement, which is often not the case in real-world bowling. This function may be part of a strategy to motivate new users to continue playing Wii bowling and other games on the Nintendo Wii.

Motion capture systems are often used by video game designers when creating realistic character movements. However, motion capture and video games do not often come together for academic research purposes. The motion capture system used in this study focused on capturing the amount of flexion and hyperextension of participants' arm movements at the shoulder. While this 2D movement is a major component of the bowling arm swing motion, we believe that future studies attempting to understand the bowling arm movement should utilize a 3D system and help examine the role of the more subtle arm movements and their impact on performance.

Further research is also needed to explore the non-significant trends observed during this study. A longer trial period should be used as the thirty trials may not have been enough to observe the true change in ROM and scores associated with learning to play Wii bowling, or the differences between the groups. Additionally, a larger sample size is necessary to determine if real-world ten-pin bowling experience has an influence on performance and movement during an initial Wii bowling practice.

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