Evaluating Video Game Controller Usability as Related to User Hand Size

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Abstract
The Xbox 360 controller, the Playstation 3 controller, and the Wii Remote and Nunchuck combination controller were evaluated in relation to user hand size. The effect of hand size on both user preference and on ease of use was considered. In a study with 13 participants, a significant relationship was found between hand size and ease of use over all controllers. Participants with larger hands were able to easily operate a larger number of control inputs than those with smaller hands. No significant relationships were found between user preference and hand size.

Author Keywords
Human-computer interaction; video game controllers; usability; hand size; user study.

ACM Classification Keywords
H.5.2. Information interfaces and presentation: User Interfaces —*Input devices and strategies (e.g., mouse, touchscreen).*

General Terms
Human Factors; Design; Measurement; Performance; Experimentation.

Introduction

Video games have substantially increased in popularity over the last few decades. The industry has grown so much that the global revenue is now comparable to that of the movie industry [7]. Unlike the movie industry though, video game producers are not just concerned with the quality of the picture, audio, and storytelling, they are also concerned about the overall playability of their games. To make games more enjoyable and playable, developers are now focusing on usability to reduce player frustration.

Related Work

There are many factors that can influence the experience of the player. Work by Pinelle et al. [4] and Federoff [2] focuses on the game design aspect. Game design encompasses anything dealing with a particular game title (i.e., user interface, control mapping, and artificial intelligence algorithms). The concern is with the software of the game and not with the underlying hardware. Pinelle et al. present a formal method of evaluating usability. The method was derived by analyzing reviews of 108 different games to identify categories of usability problems. Based on this analysis, a list of twelve common classes of usability problems was created. Of the identified twelve classes, five relate to the interface:

- unpredictable / inconsistent response to user`s actions
- clumsy input scheme
- difficult to control actions in the game
- command sequences are too complex
- response to user's action not timely enough

Also, of ten suggested improvements three relate to the interface:

- provide consistent response to the user's actions
- provide intuitive and customizable input mappings
- provide controls that are easy to manage and that have an appropriate level of sensitivity and responsiveness

This makes sense as it is through the controller that the player interacts with the game world, so any deficiency here is quickly noticed.

In the second paper, current usability practices are examined with suggestions for improvement made. Current usability practices deal with control of the game. Response time and control standardization are identified as important issues game developers should consider. The paper also discusses that while companies are now interested in usability, they do not yet have a formal method of achieving or evaluating it. The paper concludes with suggestions for creating a more formal usability evaluation method that includes a list of game heuristics that should be adhered to. Once again, many of these heuristics are related to the game controller. Problems with game interaction can occur not just in the control mappings, they can also occur in the controller itself. While the usability of games has been studied in these two papers and others, a video game controller's effect on the overall enjoyability of the gaming experience remains a relatively unexplored topic.

In modern systems there are many types of video game controllers, from the more classical controllers,

like the Xbox 360 Gamepad Controller or the Playstation 3 Dualshock 3 controller, to more recent systems like the Nintendo Wii Balance Board or the Xbox 360 Kinect. In this paper, we focus is on the standard handheld controllers of the current generation of gaming systems, specifically the Xbox 360 Gamepad Controller (Figure 1), the Playstation 3 Dualshock 3 controller (Figure 2), and the Nintendo Wii Remote and Nunchuck Controller combination (Figure 5). These controllers were chosen as they all have a similar control scheme of buttons, analog sticks, and directional pads (D-pads). Also, many of the same game titles are available for all three platforms.

Figure 1. Xbox 360 gamepad controller.

While the usability of video game controllers has never been directly studied before, video game controllers are akin to handheld tools. In this respect there is a basis for comparison. Studies of the usability of handheld objects have been conducted for many years in other areas of research. The results of these studies are mostly summarized by Sperling et al. [6]. Research indicates that hand size and hand strength both contribute to the usability of any hand tool. Most relevant to the study of game controller usability are the studies of the size of basketball best suited for children [5] and the relationship between a surgeon's hand size and the difficulty that she or he has using surgical instruments [1]. This research demonstrates that there is a relationship between the size of the user's hand and whether a tool is optimal for them or not.

Figure 2. Playstation 3 Duelshock 3 controller.

In the paper about finding the basketball best suited for children, the effect of varying a basketball's size on the score, technique, and preference of children was examined. In the study, a men's, women's and a junior

Figure 3. User with large hands can easily reach every button.

Figure 4. User with small hands must adjust their grip on the controller to reach more buttons.

standard basketball were compared. While there was little difference in technique between the three balls, there was a significant preference for the junior size ball. It was also interesting to note that performance statistically improved when the child was using the ball that she or he preferred even if it was not the one she or he used most frequently. This, when combined with the knowledge that only three children in the study had previous experience with a junior regulation basketball, indicates that the children did not perform better with the smaller ball simply because it was familiar. When children used the junior standard basketball, the relationship between the ball size and their hand size was comparable with that of adult males and a men's regulation basketball.

In the medical paper on surgeon tool use, hand size was found to be a significant determinant of the difficulty using laparoscopic surgical instruments. The study surveyed 726 laparoscopic surgeons about whether they experienced any difficulty with five different laparoscopic instruments. It was found that surgeons who used glove sizes 6.5 or smaller reported more difficulty with instrument use, particularly with the stapler. It was concluded that based on hand size alone 36% of surgeons (87% of female surgeons and 22% of male surgeons) are expected to experience significant difficulty using the tools. Ultimately, it was suggested that manufacturers of these tools should consider hand size variability in future designs.

Based upon these studies in other disciplines it can be concluded that controller size for gaming might have a significant effect on a player's preference and performance. As seen in Figure 3 and Figure 4 the differences in adult hand sizes can be substantial. A controller better suited for a player's hand size could make operation of the game easier and ultimately lead to less frustration and more enjoyability.

Figure 5. Wii Remote controller (left) and Wii Nunchuck controller (right).

The standard method of measuring hand size is the *volumetry method*. With this method, a subject's hand is submerged in water and the displacement is measured. This method is difficult, time consuming, and often expensive. The *figure-of-eight method* was designed to be easier and just as reliable as volumetry measurement [3]. In this method, the participant's hand is measured using string or a flexible tape

measure. The string or tape is wrapped around the participant's hand so that it starts at the wrist and crosses the back of the participant's hand before ending back at the wrist (see Figure 6). Measurements generally yield about 13 inches for a small hand and about 19 inches for a large hand.

The remainder of this paper is organized as follows. First, the user study developed to test video game controller usability and preference is described. After this, the overall results of the study are presented and discussed. The paper then concludes with a brief summary and thoughts about future work.

Methodology

Participants

A sample of 13 individuals from the local university campus volunteered to participate. Participants were an average of 32 years old with a median age of 30 years. Nine were male and four were female. Every participant but one was right handed and most were familiar with all controllers being tested. Each individual provided informed consent before participation.

Equipment

A standard piece of string and a tape measure were used for measuring participants' hands. Also, a Wii Remote and Nunchuck (see Figure 5), a Playstation 3 Duelshock 3 Wireless Controller (see Figure 2), and a Xbox 360 Wireless Gamepad Controller were used (see Figure 1).

Procedure

First, the size of the participant's dominant hand was measured using the figure-of-eight method described in the related work section. After the participant's hand size was recorded the participant was given a brief questionnaire about her or his background. The questionnaire recorded gender, age, and information about previous video game controller usage.

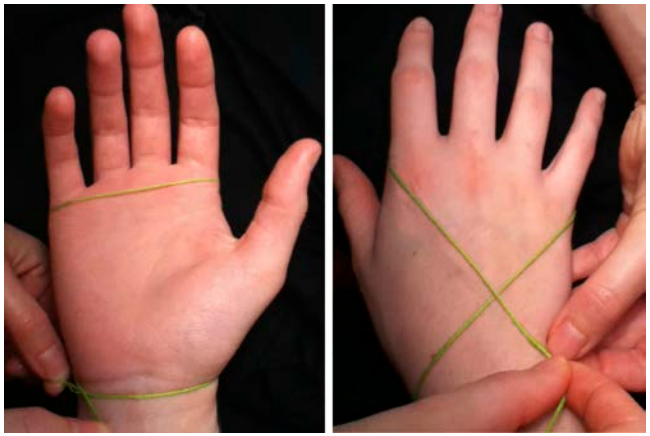

Figure 6. The figure-of-eight method of measuring hand size.

At this point, the participant was given one of the three controllers and asked to hold it in a natural position. The order that participants received controllers was counterbalanced so that the six possible orders were represented roughly equally (with two participants for each order, except for order one, which had three participants). For the Wii controller it was noted which hand the user chose to hold the Wii remote and the Nunchuck.

Once the participant found a natural position, the relative locations of the participant's fingers were noted so that the experimenter could ensure that this position was returned to between button presses. After this was done, the participant was asked to operate each of the

control inputs on the device one at a time. For each control input, the experimenter observed and recorded whether a "movement of the hand" was performed for the participant to reach it. A movement of the hand is defined as any hand movement that involves moving the grip on the controller out of the "natural" position. For example, moving only the thumb upwards to press a button would not be considered a movement of the hand, but moving the thumb so that either the entire hand had to shift position or the controller's position had to be shifted by the opposite hand was considered a hand movement. Between operating each control input, the participant was asked to move her or his hands back to the "natural" position before the next control input was operated.

After this was done for all the control inputs on the controller, the participant was given the next two controllers (according to the order group she or he was in) and the procedure was repeated. The total number of control inputs operated by each participant was 48 (the D-pad counts as four because of the four directional presses possible). The number of control inputs by controller was as follows:

Xbox 360 → 16 control inputs: 10 buttons (the "connect" button and "guide" button are excluded as they are rarely used during gameplay), two analog sticks, and one D-pad.

Playstation 3 Duelshock 3 → 18 control inputs: 12 buttons (the two analog sticks also serve as buttons if pressed and the "PS" button is excluded as it is rarely used during gameplay), two analog sticks, and one D-pad.

Wii Remote and Nunchuck → 14 control inputs: 8 buttons (the power button and home button are excluded as they are rarely pressed during gameplay), two analog sticks (for the Wii remote the optical sensor is considered a secondary analog stick as it is treated as such), and one D-pad making it the controller with the fewest number of inputs (accelerometer input was not considered).

I like the XBOX 360 controller (Please Circle)

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Why?

_____

I like the PS3 controller (Please Circle)

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Why?

_____

I like the Wii controller (Please Circle)

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Why?

_____

Figure 7. Controller preference questionnaire.

When all 48 control inputs had been accessed the participant was given a final questionnaire soliciting a rating on how much they liked a given controller and why (see Figure 7). This questionnaire was given in the form of a Likert scale to allow for statistical analysis of data; but open-ended space was provided below each response to determine whether the participant

consciously liked or disliked a controller because of its size.

Results

The relationships between participant hand size and the number of buttons reached by moving out of the "natural" position and between participant hand size and her or his preference were both examined. Results on the number of hand movements are presented first. This is followed by the results on controller preference. Lastly, the relationship between previous controller use and controller preference is considered.

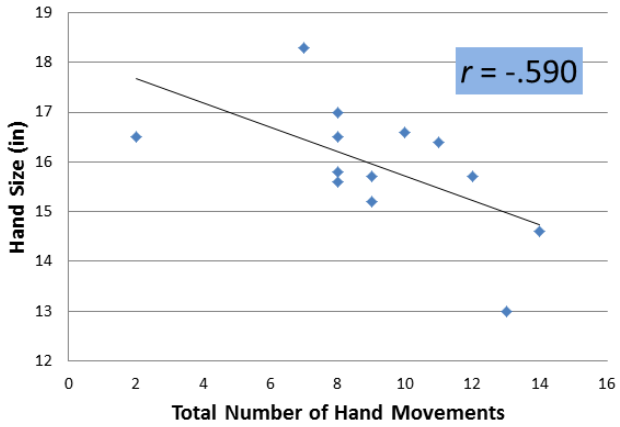

Figure 8. Total number of hand movements by hand size.

Hand Size

The 13 participants had a mean hand size of 15.9 inches (*SD* = 1.2) with a maximum hand size of 18.3 inches and a minimum hand size of 13.0 inches.

Hand Movements

The result of the total number of hand movements for all controllers is shown in Figure 8. The mean number of hand movements performed by each participant was 9.2 (*SD* = 3.1). The correlation between hand size and number of hand movements was r = -.590, which was statistically significant (t_{11} = 2.43, p < .05). The conclusion is that participants with larger hands can often reach more buttons on the controller without having to move their hands out of the "natural" position.

Next, the relationship between individual controllers and hand size was looked at. Of the three controllers, the Xbox 360 controller was the only one to have a statistically significant correlation (r = -.697) between the number of hand movements and the size of the participant's hand (t_{11} = 3.22, p < .01). This strong correlation in the Xbox 360 controller, seen in Figure 9, is possibly because this controller has the largest dimensions of the three (6.05 in width, 4.13 in height, and 2.41 in depth) and so more buttons are inaccessible to those with smaller hands.

The Wii Remote, while smaller than the Xbox 360 controller and the Playstation 3 controller, is only operated by one hand and so has the highest mean of hand movements at 4.8 (the Xbox 360 and Playstation 3 had 2.4 and 2.0 respectively). The distance between buttons on this controller is so great that even those with larger hands must move their hands out of the "natural" position to reach all control inputs. The Nunchuck is much smaller and all three control inputs could be reached by every participant without having to leave the "natural" position. Ultimately, it is theorized that the Wii Remote

component of this controller is too large to provide significant benefit to users of any particular hand size – making this the most difficult controller to operate.

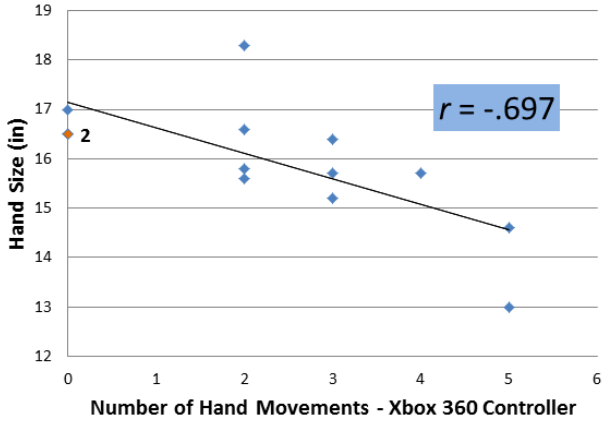

Figure 9. Number of hand movements for Xbox 360 controller by hand size (overlaps indicated by number).

The last controller is the Playstation 3 controller. This controller was notable for how consistent it was between participants of various hand sizes. While the other two controllers had some level of correlation (significant or not) between hand sizes and number of hand movements, this controller had none (r = .065). Of the 13 participants, 10 had to move their hands out of the natural position for only two buttons (the "start" and "select" buttons). It is theorized that the buttons on this controller were so easily accessible that, again, there was no significant benefit to users of any particular hand size.

User Preference

Based on the results for hand movements, it might be expected that users' preferences also have a correlation with hand size. This is far from the case.

If we compare the results of user preference by hand size for the Xbox 360 controller (shown in Figure 10) with the results of the number of hand movements for this controller (shown in Figure 9), we see that the preference results are almost random (r = .238), compared to the strong correlation that was seen with hand movements. In the preference graph, how much a participant likes the controller ranges from 1 to 5, with 1 corresponding to strongly disliking the controller and 5 corresponding to strongly liking the controller. While participants with smaller hands may have a harder time operating the control inputs, this did not seem to affect how much they liked the controller. This result was rather surprising as it is expected that an item that is harder to operate would be less enjoyable, as occurred in the basketball size study (see related work section).

The user preference results for the other two controllers also show a weak correlation with r = .070 for the Playstation 3 controller and r = .325 for the Wii controller combination. These results were essentially random when compared to participant hand size. Participants did seem to prefer the Playstation 3 controller to the Wii controller (mean number of hand movements for the Playstation 3 was 3.5 and for the Wii 2.8) but the difference in preference between the controllers was not statistically significant ($F_{2,24}$ = 1.67, p > .05).

Looking more closely at the comments in the user preference questionnaire, only a few participants

indicated they liked a particular controller because of its usability. Most participants left the open ended response blank, but those that did respond often indicated that they liked a controller because they "used it most often" or because they found it similar to another controller that they were familiar with. This indicates that each participant might carry a bias from her or his previous experience toward what controller she or he would like. Perhaps these results would be different if participants were to play a video game with these controllers, instead of just pressing the control inputs. This would enable them to become familiar with each controller and be more actively aware of the benefits and shortcomings of each.

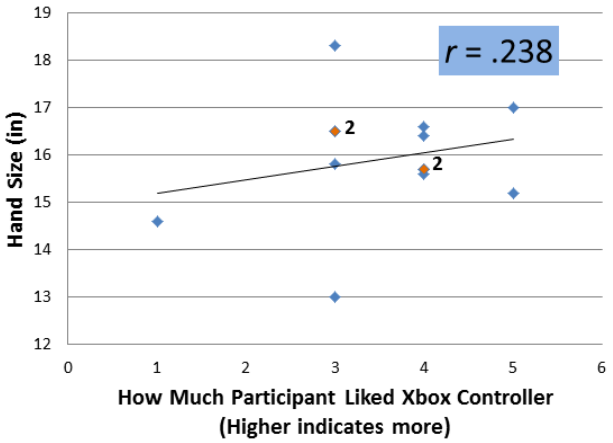

Figure 10. User preference of Xbox 360 controller by hand size (overlaps indicated by number).

Previous Controller Use

Looking more closely at the potential bias discussed in the previous section, it was determined that this bias was statistically significant for the Xbox 360 controller (t_{11} = 2.22, p < .05) but not for the other two controllers. The Xbox 360 controller correlation (shown in Figure 11) is a fairly strong relationship with only one outlying point. Previous controller use in this graph ranges from 1, indicating that the participant has never used the controller, to 4, indicating that the participant uses the controller at least once a week.

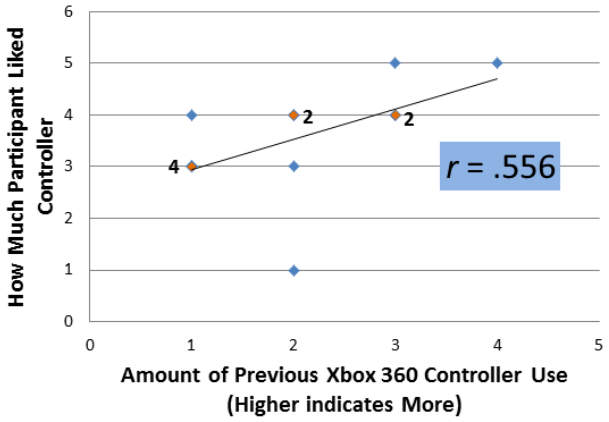

Figure 11. Previous Xbox 360 controller use by user preference of controller (overlaps indicated by number).

It is unclear why a statistically significant trend between controller preference and the amount of previous experience only appears for the Xbox 360. It would be expected that this trend would appear for all controllers. A possible explanation is that, for some controllers, participants use them frequently even though they don't like them. This might be because they enjoy the games available for that gaming system or that they own the gaming system simply because it is affordable. It is also possible that even though

participants don't use a controller often, it is not because they do not like the controller. It could just be that the price of the system is too high. For example, the price of a new Wii system is about half that of a new Playstation 3 system which could seriously affect the prior experience of participants, particularly casual gamers.

Conclusion

A user study was conducted to study the effect that a player's hand size had on her or his preference and ability to use various video game controllers. Three controllers were studied: the Wii Remote and Nunchuck controller combination, the Xbox 360 Wireless Gamepad controller, and the Playstation 3 Wireless Duelshock 3 controller.

In the user study, the relationship between the total number of control inputs that required a hand movement was shown to be statistically significant. Participants who had larger hands could reach more buttons without moving out of the "natural" position than those with smaller hands. When looking at each controller individually, only the Xbox 360 was shown to have a statistically significant relationship between participant hand size and the number of control inputs for which activation required moving the hand from the "natural" position. This relationship was shown to be stronger than that of the relationship over all controllers. For the relationship between user preference and hand size, no statistical significance was found with any of the three controllers. Finally, the relationship between previous controller use and controller preference was only statistically significant for the Xbox 360 controller.

This research demonstrates that a user's hand size has as effect on her or his experience with different game controllers. While significant results were found for the effect that hand size has on usability, no significant results were found for the effect hand size has on preference. Further research is needed to determine if this result was due to the lack of experience some participants had with operating the controllers in real game settings.

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