Enhancing Gamepad FPS Controls with Tilt-Driven Sensitivity Adjustment

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***Abstract*—Playing a first person shooter (FPS) game using a gamepad is inherently more difficult than playing it with a mouse. In this study, we propose a novel input method for gamepads to improve the FPS aim task. We take a user-centric approach to identify unused secondary motions to be indicative of players' intents. We consider the gamepad tilt as a secondary motion that users naturally perform while playing with the gamepad, and interpret it as the intent of the user to move the FPS aim faster. We use a tilt sensor to detect the amount of tilt, and use it to increase the sensitivity of the gamepad analog joystick when the gamepad is tilted. We compare this to two other input methods: a pure gamepad and a tilt-aim scheme. Our experiments show that our approach is statistically better than the tilt-aim approach, and is comparable with the pure gamepad approach.**

Keywords—video games, gamepad, first person shooter, tilt input, sensitivity adjustment, human-computer interaction

I. Introduction

First person shooter (FPS) games are one of the most popular genre of games with a big market and an increasing number of titles released every year [1]. FPS games typically provide a fast-paced gameplay experience, in which the user interacts with the game world from the point of view of the avatar. FPS games are popular both in PCs and in game consoles; however, console gamers are typically disadvantaged in FPS games because the gamepad is not an ideal input device for FPS games.

Conceptually, the inputs that an FPS game requires typically consist of a 2D vector for walk and strafe, a 2D position in polar coordinates for aiming at the objects in the environment, and various triggers for interacting with the aimed object (use, take, shoot, etc.) Acquiring targets by aiming quickly at the correct object is very important in fast-paced FPS games. Therefore, the input device used for the aim should be appropriate for providing the desired 2D position in polar coordinates. In PCs, the mouse is used for aim and its 2D position on the mouse pad provides a good approximation for the 2D position in polar coordinates—the continuous on-screen visuals provide sufficient feedback for the player to determine and update the desired target position for the mouse. This enables players to aim at targets quickly and correctly in PCs.

Gamepads are the standard controllers for popular game consoles, most notably Xbox One and PlayStation 4. The two analog joysticks of gamepads enable users to input continuous 2D vectors within a 2D unit disc. To aim in FPS games, players control the 2D position in polar coordinates using the right analog joystick. However, unlike the mouse, the analog joystick does not let the user directly input a 2D position. Rather, the user inputs a 2D velocity in time, and uses it to arrive at the desired 2D position. Compared to the mouse, this is an indirect way of controlling the aim. Rather than directly providing the desired position, the user has to provide a series of velocities that will cause the aim to arrive at the desired position.

This indirect input for aim puts console FPS players at a disadvantage. As a result, game companies typically do not mix PC and console FPS gamers in online games [2] and add features such as aim-assist (auto-aim) to help console players. We believe that this inequality between PC and console gamers provides Human-Computer Interaction researchers with an opportunity to improve the FPS gaming experience in consoles and help many console players enjoy FPS games more.

Some modern gamepads have integrated inertial controllers that can track the orientation of the gamepad in space, e.g., Sixaxis and DualShock 4 controllers from Sony contain three-axis accelerometers and gyroscopes. However, using the gamepad orientation to control FPS aim directly has not created successful interactions. Therefore, FPS games use these sensors for simpler tasks such as shake detection and leaning the character around walls.

In this study, we propose a novel input method to make use of inertial sensors of gamepads to enhance the FPS aiming experience. We take a user-centric approach and make use of secondary motions that users automatically perform while playing FPS games with gamepads. Our input method increases the sensitivity of the analog joystick in response to the tilt angle of the gamepad. We compare this approach with the state of the art in a within-subjects study and show that it is better than using the gamepad orientation for controlling aim directly. Our results also suggest that this method may enhance aiming with the gamepad.

II. Related Work

A. Gamepads for Aiming

Researchers previously reported issues related to position input with the analog joysticks of gamepads. Natapov et. al. [3] studied the use of the gamepad for point-select tasks. They compared the gamepad to mouse and Wii remote IR pointing, and showed that "analogue stick targeting is not a good method for performing point-select tasks". They later replaced the right analog joystick with a trackball to enable direct position control [4], and showed that this resulted in better user performance in games [5].

Several researchers have studied the use of the gamepad in FPS games, and have concluded that the direct position input of the mouse is better than the gamepad in the essential FPS task of target acquisition [6]–[10]. Nevertheless, players are still using the gamepad in consoles to play FPS games. This may be because it provides a noise-free and lag-free way to play games, unlike some other novel sensor technologies. Ardito et al. showed that for positioning tasks, gamepads are preferable to tilt-based accelerometer inputs [10]. Similarly, Zaranek et al. showed that for FPS target acquisition, gamepads are preferable to the Kinect and the Move input devices [11] that are both susceptible to noise and lag since they rely on computer vision. Therefore, gamepad is still preferred in consoles for FPS games, and improving the gamepad experience in FPS games can enhance the experiences of many console gamers.

B. *Tilt Inputs in Games*

Low-cost three axis MEMS accelerometers and gyroscopes are used for detecting tilt as input in devices such as mobile phones, tablets and the Wii remote controller. A number of modern gamepads also contain tilt sensors (e.g., Sixaxis and DualShock 4). Therefore, techniques that enhance the gamepad experience with tilt sensors can be practically used with gamepad controllers that already contain these sensors.

Tilt input has been used extensively in mobile games. Multiple researchers have shown that in simple mobile games, tilt controls competes with touch controls in terms of game success and user preferences [12]–[15]. However, a fundamental investigation of Fitts' law for tilt controls show that tilt is not a precise method of input [16] and therefore may not be suitable for games that require precision. Further research shows that using tilt as velocity input (similar to gamepad analog joystick) is less precise than using tilt for position input in which the orientation is mapped directly to position [17].

C. *Tilt Inputs in FPS Games*

The research on tilt inputs in FPS games and similar VR navigation tasks is limited. For the fundamental aiming task of FPS, tilt inputs were shown to be better than discrete button inputs [18], but worse than the gamepad analog joystick as well as the mouse [10]. These findings indicate that tilt is not an appropriate input for aiming. This is also reflected in the games industry. Tilt was found to be "not sensitive enough" by developers of Resident Evil 5 [19] and accelerometers are not integrated in Xbox 360 controllers because of similar reasons [20].

Some mobile FPS games have implemented aiming by moving the device (Cube for iOS, MosKillTo for iOS, Call of Duty Strike Team for iOS), which are likely to suffer from the shortcomings of tilt-based aiming. A notable example is Uncharted: Golden Abyss for PlayStation Vita [21], in which the user fine-tunes the aim by moving and tilting the device after drawing the weapon. The larger motions of the aim and the navigation of the avatar are performed using the analog joystick and without the device motion. Isolating the tilt inputs to be used only for precise aiming and not for general aiming appeared to help improve tilt-based interaction for this game.

Many mainstream FPS games for the PlayStation Sixaxis controller have opted not to use tilt input for aiming. They preferred to use the motion inputs for secondary actions such as leaning near walls (Battlefield 4), having to keep the gamepad still while aiming with the sniper rifle (Killzone 2), shaking the gamepad to change attire, looking around under a dumpster lid, and shaking the enemy with a magical doll (Metal Gear Solid 4).

There is a notable exception that is also related to our approach of using tilt for sensitivity adjustment. Killer Freaks from Outer Space (which was later released as ZombiU) makes use of the combination of high-precision accelerometer, gyroscope and magnetometer in WiiU to use the controller's orientation for FPS aiming [22]. The game detects the speed of the user's motions to adjust the sensitivity of aim so that slower motions would be used for precise aiming and faster motions would be used for larger motions of the aim. This is similar to the well-known approach of mouse pointer acceleration. While it relates to our approach in that it also adjusts FPS aim sensitivity according to user input, it is a simple adjustment using the main mode of motion input (i.e., adjusting tilt sensitivity using tilt speed). Ours is different in that we use the user's otherwise unused secondary motions to improve the non-motion based input method of aiming with the gamepad analog joystick.

III. APPROACH

We take a user-centric approach to find an effective way of using tilt sensors to enhance FPS aiming with the gamepad. We use the secondary motions that users already perform while playing with gamepads, and adjust the aim sensitivity accordingly.

Most input devices require a specific set of motions to play a game (e.g., moving the mouse with the hand, moving the analog joystick of a gamepad with the thumbs, etc.). When users are engaged deeply with a game, they sometimes tend to perform other motions that are not required and are ignored by the input device (e.g., moving the head while dodging attacks in an FPS, tilting the gamepad when failing to steer a car during a sharp turn, etc.). While a behavioral study is necessary to better understand these commonly-observed secondary motions, we believe that they contain useful information that reflect the intentions of the user. Specifically, we assume that users tilt the gamepad when they want the avatar to move faster than the maximum velocity possible with the analog joystick. We believe that these unused motions can be used to enhance the game experience.

In this study, we make use of these otherwise ignored secondary motions to better reflect the user's intentions in the game. For example, the intentions of the user may be different in the following two behaviors: (1) moving the analog joystick all the way to the right without moving the gamepad itself, (2) moving the analog joystick all the way to the right and also tilting the gamepad to the right. We assume that in case (2), the user intends to move the avatar faster compared to case (1).

Therefore, we use the amount of gamepad tilt to make the avatar really move faster in case (2). By using the amount of tilt to adjust the magnitude of the velocity input, we aim to better reflect the user's intentions in the game. As the user tilts the gamepad more, we effectively increase the sensitivity of the analog joystick input and move the crosshair with higher velocities, allowing the user to aim quickly to targets that are away from the crosshair. Holding the gamepad in a level pose reduces the sensitivity of the analog joystick and allows the user to aim precisely on targets that are close to the crosshair. This way, we aim to reflect the user's intentions more closely in the game.

We implement this sensitivity adjustment for the analog joystick in a simple way. We track the sensitivity separately for X and Y axes. We use the roll angle of the gamepad to adjust the sensitivity for the X axis of the analog joystick and used the pitch angle similarly for the Y axis. We used the equations below to compute the velocity input by the analog joystick.

$$v_x = \left(s_x^0 + s_x^1 \frac{|\psi|}{\pi}\right) v_x^0$$

$$v_y = \left(s_y^0 + s_y^1 \frac{|\phi|}{\pi}\right) v_y^0$$

In the equations above, v_x^0 and v_y^0 are the components of the raw velocity input from the analog joystick, ψ is the roll angle, ϕ is the pitch angle, s_x^0 and s_y^0 are the sensitivity when the gamepad is level, s_x^1 and s_y^1 are the sensitivity increases when the gamepad is turned 180 degrees, and $v_x$and v_y are the velocity components that is provided as an input to the game. We use the absolute values of the angles so that sensitivity increases both for right and left when the gamepad is tilted to the left.

To determine the values of sensitivity coefficients for our implementation, we conducted a simple pilot test in which we tried different values and subjectively assessed the playability of the game with different sensitivity values. As a result, we chose $s_x^1 = 6s_x^0$ and $s_y^1 = 6s_y^0$ as the sensitivity coefficients to be used in our usability tests.

With this scheme, the crosshair's motion velocity was controlled both by the analog joystick and the gamepad tilt. The analog joystick provided the direction and the base magnitude of the velocity. The degree of tilt scaled the magnitude of this velocity so that the crosshair moves faster when the gamepad is tilted.

IV. Method

In a within-subjects design, we compared our novel input method of using tilt to adjust gamepad sensitivity to two other input methods: conventional gamepad input and using gamepad tilt to aim.

A. *The game*

We used the FPS constructor tool for the Unity 3D game engine to create a simple FPS game that can be controlled with the different input methods that we aimed to compare. In the game, the user controls an avatar with a rifle and views the game world from the avatar's point of view (see *Figure 1*). The goal is to kill all the enemies that are spawned simultaneously from four different locations in four waves in a square map surrounded by walls. The next wave started after the player kills all the enemies in a wave. We did not let the avatar die in the game to avoid shorter sessions and to enable fair comparisons between the input methods. Therefore, the game session continued until the player killed all the enemies in the last wave.

Figure 1. The game that we used in the experiments.

B. *Hardware*

We used a conventional PC gamepad with an analog joystick for the input device. This gamepad did not contain integrated sensors to detect tilt. To track the tilt, we used a Texas Instruments ez430 Chronos Sports Watch that has a three-axis accelerometer. We removed the body of the watch from its wristband, and taped it on the bottom of the gamepad (see *Figure 2*). The watch communicated wirelessly with the PC via its USB dongle and provided approximately 20 three-axis accelerometer readings per second. Using a lowpass filter, we tracked the direction of gravity and computed the pitch and roll angles that represented the tilt of the gamepad compared to the default orientation that we captured at the beginning of the game.

Figure 2. The gamepad and the accelerometer.

C. *Conditions*

Our experiment had three conditions: Gamepad, Tilt and Sensitivity.

Gamepad: This condition reflected the conventional way of playing FPS games with a gamepad. The player used his or her thumbs to operate the two analog joysticks. The left analog joystick moved the avatar without changing the aim direction (walk/strafe) and the right analog joystick changed the aim direction of the avatar.

Tilt: This condition reflected the state of the art for FPS games that use the tilt to control the aim direction. The amount of tilt in the pitch and roll angles determined the velocity for the aim direction in the vertical and horizontal planes (i.e., the character constantly turned right while the user is tilting the gamepad to the right).

Sensitivity: This condition represented our novel input method for FPS games, in which we track the gamepad tilt to make use of the user's secondary motions while playing the game with the analog joysticks. As explained in Section III, we use the amount of tilt to scale the magnitude of the velocity input of the right analog joystick that is used for aiming.

The three conditions differed only with respect to how the aim in the game is controlled with user input. In all conditions, the player used the R1 button with the right index finger to shoot, and the left analog joystick to walk and strafe.

D. Participants

We recruited 13 participants through announcements in university lectures. We used two of these participants in our iterations on the input method and experiment design. We used the rest of the 11 participants (one female, ages 20-25) in our within subjects experiment. Participants' experiences in gaming, FPS games and gamepads varied.

E. Sessions

Sessions took place in a quiet office environment. Each user participated in only one session. After signing a consent form, the participant sat in front of a laptop computer and used the gamepad to play the three game conditions in succession. We counterbalanced possible learning effects with a Latin Square design. We conducted semi-structured interviews and questionnaires at the beginning of the session, after the user played each condition, and at the very end of the session. Before playing each condition, we briefly explained how the inputs worked and the game allowed the user to practice for one minute. Afterwards, the user played the game in which enemies attacked in four waves. New waves started after all enemies in the previous wave were dead. The game ended when the user killed all the enemies in the last wave. After the game, the user filled in a questionnaire about the input method that he or she just used. At the end of the session, we conducted a semi-structured interview in which the user commented on his or her experiences with the different input methods.

F. Data

In the beginning of the session, we collected data about the user and his or her experiences with video games and gamepads. We collected the different platforms that the user plays games in, whether the user plays FPS games, whether they play FPS games online, whether they played an FPS game with the gamepad and if they did, how much they liked it.

While playing the game, we tracked how long it took the user to complete the game (dependent variable, DV 1). We assumed that a short game duration would reflect the success of the input method as the efficiency of target acquisition would result in the user killing the targets faster. We also collected how many times the user was shot, i.e., how much damage the user received (DV 2). We assumed that this would reflect the difficulty of using the input method as the user may get shot more because of not being able to evade attacks due to the mental load that the input method requires, and also because of not eliminating the enemies quickly. In addition, we kept track of users' missed shots (DV 3) to reflect their failure to acquire targets, which may be caused by the input method.

TABLE I. AFTER-GAME QUESTIONNAIRE

DV	Question	Answer
DV 4	Was it easy to play the game?	Likert (1-5)
DV 5	Was it easy to get used to this input method?	Likert (1-5)
DV 6	Was it easy to kill nearby enemies?	Likert (1-5)
DV 7	Was it easy to kill far enemies?	Likert (1-5)
DV 8	Was the game fun to play?	Likert (1-5)
DV 9	Do you think you would be successful in the game once you got used to this input method?	Likert (1-5)

After each game, the user filled the questionnaire in Table 1. (DV 4-9) After the third game, at the end of the session, we asked users about their choices in input methods (DV 10) and users ranked the three input methods that they have experienced.

V. RESULTS

A. Statistical Analysis

We analyzed each of the 10 dependent variables (see *Figure 3*) in an analysis of variance with input method (Gamepad vs. Tilt vs. Sensitivity) as a within-subjects factor. We verified the sphericity assumption with Mauchly's test of sphericity for all variables, except for damage received and fun factor ($p>0.05$). We used the Huynh-Feldt correction for these variables in the following analyses. Using repeated measures analysis of variance (RM-ANOVA) for each variable, we found that the main effect of the input method was significant for the following variables: game duration (DV 1), damage received (DV 2), and perceived ease of use (DV 4). For each of these variables, we performed post-hoc comparisons using the Fisher's LSD test to further uncover the effects of the input method. Below we analyze each of these variables in detail.

Game duration (DV 1). RM-ANOVA showed that the main effect of the input method was significant with $F(2, 20)=10.186$, $p<0.005$, $\eta 2=0.505$. Post-hoc comparisons using the Fisher's LSD test indicated that players spent significantly more time to finish the game in the Tilt case (M=199.18, SD=44.546) compared to both the Gamepad case (M=158.64, SD=29.659, $p<0.005$) and the Sensitivity case (M=171, SD=33.791, $p<0.05$). This may indicate that Tilt was more difficult to use than both Gamepad and Sensitivity.

Damage received (DV 2). RM-ANOVA with Huynh-Feldt correction showed that the main effect of the input method was significant with $F(1.207, 12.067)=4.532$, $p<0.05$, $\eta 2=0.312$. Post-hoc comparisons using the Fisher's LSD test indicated that players received significantly more damage ($p<0.05$) in the Tilt case (M=69.45, SD=61.876) compared to the Gamepad case (M=38.27, SD=26.661). This may mean that Tilt required more mental load compared to Gamepad. The players received even lower damage on average in the Sensitivity case (M=34.18, SD=23.302), however the differences are not statistically significant.

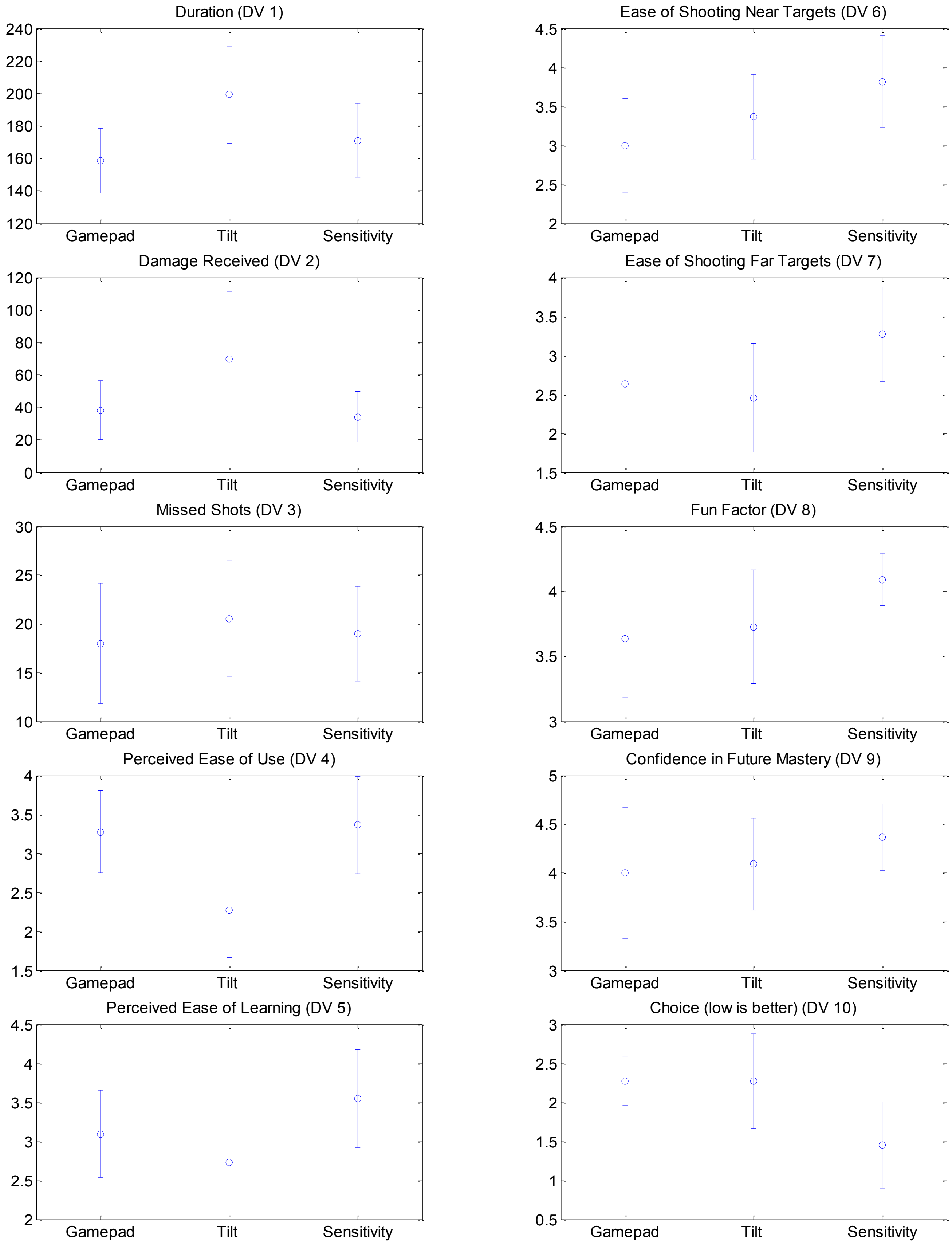

Figure 3. Estimated distributions of dependent variables. Error bars indicate 95% confidence intervals.

Perceived ease of use (DV 4). RM-ANOVA was significant with $F(2, 20)=7.151$, $p<0.005$, $\eta 2=0.417$. Post-hoc comparisons using the Fisher's LSD test indicated that players found both the Gamepad case (M=3.27, SD=0.786, $p<0.001$) and the Sensitivity case (M=3.36, SD=0.924, $p<0.05$) significantly easier than the Tilt case (M=2.27, SD=0.905). This may indicate that controlling aim with the tilt may be less intuitive for players compared to the other two input methods that use the analog joystick. In addition, users found Sensitivity to be slightly easier than Gamepad on average, but the difference was not statistically significant.

B. *Statistically Insignificant Observations*

The statistically significant results above favor Gamepad and Sensitivity over Tilt; however, they do not make a distinction between Gamepad and Sensitivity. We believe that the limitations of our sample size may have caused this. In order to make the best use of our data, we investigate the means of the rest of the variables to gain further insight between the two cases.

We observed that means of the questionnaire results all favor Sensitivity over the two other input methods. Average perceived fun factor is the largest for Sensitivity, followed by Tilt and then Gamepad. On average, players ranked Sensitivity better in their choice of input device compared to Gamepad and Tilt. Average perceived ease of learning is the highest in Sensitivity, followed by Gamepad and Tilt. Average perceived ease of shooting near targets is the highest for Sensitivity, followed by Tilt and then Gamepad. Average perceived ease of shooting far targets is the highest for Sensitivity, followed by Gamepad and then Tilt. Average confidence in future mastery was the highest for Sensitivity, followed by Tilt and then Gamepad. While the differences are not statistically significant, these results all favor Sensitivity, including perceived ease of use that we analyzed in the previous subsection.

The data related to users' gameplay favor Gamepad and Sensitivity. Average game duration is the lowest for Gameplay, followed by Sensitivity and Tilt. This may mean that Gamepad let the users eliminate the enemies faster. Average number of missed shots parallels this observation, as it is the lowest for Gameplay, followed by Sensitivity and Tilt. Together, the means of these two variables may indicate that users acquired targets more accurately and eliminated them faster with Gamepad, followed by Sensitivity, and then Tilt. However, damage received favors Sensitivity over Gamepad and Tilt, as the average damage received is the least for Sensitivity and is followed by Gamepad. This may mean that the mental load of the input method was the least with Sensitivity.

While the results in this section are not statistically significant, they support our qualitative observations during the user tests. Users generally enjoyed the Sensitivity input method, however; since it was a new way of interacting with a game, the learning effect may have hindered their performances.

VI. DISCUSSION

A. *Discussion of Results*

Our results indicate that it is possible to make use of tilt input to positively enhance the aim inputs in FPS games played with gamepads. The Tilt and Sensitivity input methods that we implemented to enhance the gamepad experience were simply additions to the default controls of the gamepad, i.e., the user could still play the game with the analog joystick and have a similar experience if he or she did not tilt the gamepad. However, the additional input of gamepad tilt to control the aim in the Tilt case not only did not enhance the interaction, but also significantly hindered the user experience according to the results of our statistical analysis. Whereas using the tilt to adjust the speed of aim in the Sensitivity case did not have such a detrimental effect.

We believe that having both tilt and the analog joystick control the aim simultaneously in the Tilt case created a competition between the two inputs. As the user tried to control the aim with the analog joystick, the inevitable motions of the gamepad introduced unwanted noise in the aim. This led some users to stop using the analog joystick and rely on the tilt to control the aim, which has been shown previously to be inferior to gamepad inputs [10].

In contrast, having tilt and analog joystick inputs affect aim in different but complementary ways in the Sensitivity case did not hinder the user experience. Tilting the gamepad to enable the analog joystick to move faster in the Sensitivity case resulted in a similarly successful game experience as the plain gamepad in the Gamepad case according to the results of our statistical analysis. Our qualitative observations and differences in means of questionnaires responses indicated that users received this novel input method well. When asked to rank their preferred input methods, eight out of 11 participants ranked the Sensitivity case as their first choice in the questionnaire.

B. *Relation to Previous Work*

Our results are in agreement with previous work that showed tilt inputs to be less precise compared to gamepad inputs [10]. Similarly, in our experiments, the Tilt case that used the gamepad tilt to control the aim resulted in slower completion of game tasks (longer game sessions), increased received damage, and was perceived to be more difficult compared to other two input methods.

Our work is the first to propose an alternative use for the gamepad tilt to enhance the analog joystick input in gamepads. Previous studies aimed to replace the role of the analog joystick with tilt, whereas we introduced a method to use tilt to enhance it. While we focused on FPS games, we believe that this idea can also be adapted to other types of games played with the analog joystick.

C. *Better Interpreting Users' Intentions*

A possible shortcoming of our approach is that it depends heavily on our assumption of how to interpret users' secondary motions while playing with a gamepad. As presented in Section III, we assumed that the attitude of the gamepad (i.e., how much it is tilted) reflects users' intentions of aim speed. However, there may be parameters other than the value of the tilt angle that also contain information about the user's intent. For example, tilting the gamepad faster may mean that the user wants to move the aim faster. The speed in which the user changes the attitude, among other parameters of motion, is ignored in our assumption of the meanings of secondary motions. More accurate interpretations of secondary motions that may be uncovered by behavioral studies may help create better control schemes.

D. Enhancing Existing Input Methods with Novel Sensors in a User-centric Way

As new sensors are appearing in input devices, developers and researchers are finding ways of using them to interact with games. However, the straightforward way of integrating such sensors into games may not always be the best choice. As in the case of tilt for aim, using the tilt to replace the analog joystick for entering velocity was not a good choice, possibly because the analog joystick retracts to the neutral position while tilt must be neutralized manually by the user. Using tilt to directly input a position rather than a velocity can be a better choice [17]; however, this is not suitable for FPS games as they require continuous and long motions that can wrap around in the polar coordinates. This would require the user to spin the gamepad around and keep in poses that are very different than the neutral pose. In addition, precision and input delay of accelerometers can also play a role in hindering the success of tilt for aiming.

Rather than fixating on and forcing the straightforward ways of using these devices, developers and researchers should take a step back and reconsider the abilities, requirements and limitations of these novel sensors as well as the expectations, behaviors and abilities of users that will use them. In this study, we adopted a user-centric approach and considered the naturally occurring behaviors of users as they played FPS games with the gamepad. Then, we found a way to use the tilt sensor to address the unused secondary motions of the users to better reflect their intentions in the game. Our experiments showed that this was a better approach compared to the straightforward use of tilt for aim. Through a similar user-centric approach, we can find ways to use other novel input devices to enhance the gaming experience for users. For example, even though the Kinect may not be preferred as the main input device to play fast-paced games that require quick and precise reactions, it can be used in conjunction with a gamepad to enhance the game experience.

E. Limitations

The present study has a number of limitations that should be considered while interpreting the outcomes. Firstly, the sample size in our experiments was small (11) which limits the statistical power of our study. Therefore, we opted to use the Huynh-Feldt correction instead of Greenhouse-Geisser when sphericity assumption was violated, and we used the Fisher's LSD test without the Bonferroni adjustment for multiple comparisons. Nevertheless, we found meaningful and statistically significant results that supported our qualitative observations.

Another limitation of our study is that the FPS game that we created was a simple one and represented general gameplay, rather than focusing on cases in which the advantages and disadvantages of the considered input methods would be stressed. The noise associated with regular gameplay may have prevented some of the results from being statistically significant. A better game design would be to have isolated tasks within a game that can help contrast the input methods. Comparing the data about such sections of the game rather than whole game sessions may uncover more information about the effects of the different input methods.

Another limitation is the learning effect related to novel input methods. Before each game, we included a one-minute practice session in which the user practiced and learned the input method. Instead, teaching users how to use the input methods more effectively through tutorials could help contrast the differences in the input methods.

VII. Future Work

The novel input method that we introduced in this study may lead to new possibilities for future studies, related to the improvement of the present study, using motion sensors to enhance existing methods of playing games, and better addressing the velocity-position mismatch in gamepads and FPS games.

The experiments that we presented in this study provide a convincing argument for using tilt not for aiming directly in FPS games but for adjusting the sensitivity of the analog joystick to aim in FPS games. However, the experiments do not provide statistically significant evidence about whether this novel input method or the basic use of gamepads is preferable. As a part of our future work, we plan to improve our game and experiment design in a way that will stress the differences between these input methods, and run a study with a larger sample size and more statistical power.

Another line of future work that stems from this work is to find practical uses for new motion sensors to enhance existing methods of playing games. For example, Zaranek et al.'s study [11] indicates that gamepads are preferable to the Playstation Move and Microsoft Kinect in FPS games. We believe that using a similar methodology from this study, we can find ways of making use of users' secondary motions while playing with the gamepad to enhance the game experience with these devices. For example, the Kinect can track the user's head and may help him or her dodge bullets by moving the head.

While we did not address it in this study, there is an inherent mismatch between the velocity input of the analog joystick and the position input that FPS aiming needs. Natapov et al. [4] address this by using a trackball instead of an analog joystick. We would like to search for less invasive ways of enhancing the gamepad experience with other sensors to facilitate easier position input and improve the game experience.

VIII. Conclusion

In this paper we introduced a novel way of using a gamepad and a tilt-sensing three-axis accelerometer to enhance the way that users play FPS games with the gamepad. Our input method relies on the user-centric observation that users perform secondary motions of tilting the gamepad when they are not satisfied with the current velocity of motion they can achieve with the analog joystick. By using the amount of tilt to scale the velocity provided by the analog joystick and effectively increasing its sensitivity when the user tilts the gamepad, we attempt to realize the user's intent for tilting the gamepad. We compared this method to two other input methods: a plain gamepad input and using tilt directly to aim in FPS games. We showed with statistical significance that our method does not have the detrimental effects of using tilt to directly control the aim and is comparable with the plain gamepad input. Our experiments have also suggested that our method may be preferred by users and may put less mental load on the user; however, these results were not statistically significant.

REFERENCES

[1] M. Hitchens, “A Survey of First-person Shooters and their Avatars,” *Game Stud.*, vol. 11, no. 3, 2011.

[2] “PC gamers ‘destroyed’ console gamers in tests, says Voodoo PC founder.” [Online]. Available: http://www.gamesradar.com/pc-gamers-destroyed-console-gamers-in-tests-says-voodoo-pc-founder/. [Accessed: 15-Aug-2014].

[3] D. Natapov, S. J. Castellucci, and I. S. MacKenzie, “ISO 9241-9 evaluation of video game controllers,” in *Proceedings of Graphics Interface 2009*, 2009, pp. 223–230.

[4] D. Natapov and I. S. MacKenzie, “The trackball controller: improving the analog stick,” in *Proceedings of the International Academic Conference on the Future of Game Design and Technology*, 2010, pp. 175–182.

[5] D. Natapov and I. S. MacKenzie, “Gameplay evaluation of the trackball controller,” in *Proceedings of the International Academic Conference on the Future of Game Design and Technology*, 2010, pp. 167–174.

[6] K. M. Lenz, A. Chaparro, and B. S. Chaparro, “The Effect of Input Device on First-Person Shooter Target Acquisition,” *Proc. Hum. Factors Ergon. Soc. Annu. Meet.*, vol. 52, no. 19, pp. 1565–1569, Sep. 2008.

[7] P. Isokoski and B. Martin, “Performance of input devices in FPS target acquisition,” in *Proceedings of the international conference on Advances in computer entertainment technology*, 2007, pp. 240–241.

[8] C. Klochek and I. S. MacKenzie, “Performance measures of game controllers in a three-dimensional environment,” in *Proceedings of Graphics Interface 2006*, 2006, pp. 73–79.

[9] J. Tsai and M. Stoklosa, “Evaluation of Input Devices for an FPS Program Used in Law Enforcement Tactics Training,” *Proc. Hum. Factors Ergon. Soc. Annu. Meet.*, vol. 52, no. 27, pp. 2087–2091, Sep. 2008.

[10] C. Ardito, P. Buono, M. F. Costabile, R. Lanzilotti, and A. Simeone, “Comparing low cost input devices for interacting with 3D Virtual Environments,” in *2nd Conference on Human System Interactions, 2009. HSI ’09*, 2009, pp. 292–297.

[11] A. Zaranek, B. Ramoul, H. F. Yu, Y. Yao, and R. J. Teather, “Performance of modern gaming input devices in first-person shooter target acquisition,” in *CHI’14 Extended Abstracts on Human Factors in Computing Systems*, 2014, pp. 1495–1500.

[12] P. Cairns, J. Li, W. Wang, and A. I. Nordin, “The influence of controllers on immersion in mobile games,” in *Proceedings of the 32nd annual ACM conference on Human factors in computing systems*, 2014, pp. 371–380.

[13] K. Browne and C. Anand, “An empirical evaluation of user interfaces for a mobile video game,” *Entertain. Comput.*, vol. 3, no. 1, pp. 1–10, 2012.

[14] S. Medryk and I. S. MacKenzie, “A comparison of accelerometer and touch-based input for mobile gaming,” in *International Conference on Multimedia and Human-Computer Interaction-MHCI 2013*, pp. 117–1.

[15] W. Hürst and H. C. Nunez, “Touch Me, Tilt Me–Comparing Interaction Modalities for Navigation in 2D and 3D Worlds on Mobiles,” in *Advances in Computer Entertainment*, Springer, 2013, pp. 93–108.

[16] I. S. MacKenzie and R. J. Teather, “FittsTilt: The application of Fitts’ law to tilt-based interaction,” in *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design*, 2012, pp. 568–577.

[17] R. J. Teather and I. S. MacKenzie, “Position vs. velocity control for tilt-based interaction,” in *Proceedings of the 2014 Graphics Interface Conference*, 2014, pp. 51–58.

[18] P. Gilbertson, P. Coulton, F. Chehimi, and T. Vajk, “Using ‘tilt’ as an interface to control ‘no-button’ 3-D mobile games,” *Comput. Entertain. CIE*, vol. 6, no. 3, p. 38, 2008.

[19] T. B. P. Tuesday and 3 June 2008, “Sixaxis not sensitive enough,” *Eurogamer.net*. [Online]. Available: http://www.eurogamer.net/articles/sixaxis-not-sensitive-enough-for-fps-aiming-resi-5-producer. [Accessed: 25-Jul-2014].

[20] “Microsoft Talks About Why There Are No Tilt Or Motion Sensors in the Xbox One Controller.” [Online]. Available: http://gamingbolt.com/microsoft-talks-about-why-there-are-no-tilt-or-motion-sensors-in-the-xbox-one-controller. [Accessed: 13-Aug-2014].

[21] “Uncharted: Golden Abyss video shows off gyro-aim controls,” *ComputerAndVideoGames*, 15-Dec-2011. [Online]. Available: http://www.computerandvideogames.com/329930/uncharted-golden-abyss-video-shows-off-gyro-aim-controls/. [Accessed: 20-Sep-2014].

[22] Ruthie, “Ubisoft: Wii U makes FPSs easier to control,” *Nintendo Wii U Go*, 02-Aug-2011. [Online]. Available: http://wiiugo.com/ubisoft-wii-u-makes-fpss-easier-to-control/. [Accessed: 15-Aug-2014].