Total Control:

A Survey of Modern Video Game Controller Design Considerations

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Abstract

With the rise of powerful and miniature wireless technology, there are more methods of controlling interactive video games than ever before. Three main dimensions of controller quality were identified: *naturalness*, the degree to which a controller replicates embodied action in a game; *pointing performance*, the degree to which a controller allows the player to quickly and accurately convey directional input; and *comfort*, the degree to which a controller has a practical shape and button layout. These categories corresponded loosely to three different classes of controllers: natural controllers, which include motion controllers such as the Nintendo Wii Remote and experience-recreating devices such as steering wheels; mouse/keyboard configurations, used most frequently in competitive PC gaming; and traditional two-handed thumbstick controllers, the most signature design that has existed for decades, and the one that appears on all current-generation video game consoles. A literature review aimed to understand which considerations led to the best overall game controller experience. It was found that no single style of physical controller results in uniformly better experiences than the others; rather, each style has dimensions where it excels, and other dimensions where its design limits the experience. Though thumbstick controllers in particular do not seem to excel in every dimension, it is proposed that their comparative versatility has led to their widespread dominance in the industry today.

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Video games are a rich, immersive form of entertainment. They model all sorts of universes, spanning from very lifelike to very foreign: car racing games with first-person perspectives can commendably recreate the experience of driving, while puzzle-solving games often create abstract layouts and rules that would not be easily modeled in the physical world. Because of this diversity, game controllers are often designed to accommodate a wide variety of game content, but it is unclear if such a "genre agnostic" controller leads to the best experience in all cases.

Video games are interactive by definition, and as electronics technology has improved and diversified, so have the ways to interact with digital games. Video game interface devices today take many forms: players interact with games via touchscreens, computer keyboards and mice, wireless thumbstick controllers, joysticks, racing wheels, motion-sensing handheld controllers, virtual reality (VR) headsets, television-mounted cameras, and more. This paper samples pertinent research in an attempt to better understand design considerations of modern video game controllers. It focuses on determining whether or not there is a single controller design that seems to be universally ideal for player satisfaction. Research indicates that there is no one controller design that is optimal for all game domains; rather, the different dimensions of *naturalness*, *pointing performance*, and *comfort* all influence the ideal layout of a controller.

Literature Review

Naturalness

The first dimension of controller quality is *perceived naturalness*, or the degree to which the control scheme makes the player feel like the digital experience mimics its real-life counterpart.

The principle of *embodied cognition* states that a player's own thoughts and interpretations of a video game experience will be influenced by his or her own body's position and movement. If a controller allows a player to move his or her hands and body in a more realistic way, that will lead to a stronger interpretation of the game approximating a real-life experience.

Skalski et al. (2010) studied the link between *mapping*, *mental models,* game controller naturalness and game enjoyment. The concept of *mapping* in this context is similar to *embodied cognition*: it is "the manner in which the actions performed by users of interactive media are connected to corresponding changes in the mediated environment" (Skalski et al., 2010). It is suggested that a greater degree of mapping will lead to greater controller naturalness. *Mental models* are defined as "cognitive representations of situations in real or imagined worlds" (Skalski et al., 2010). Earlier research suggests that controller naturalness leads to a quicker recall of mental models of real-world behavior, leading to greater spatial presence in the game (Tamborini & Skalski, 2006). Skalski et al. (2010) focused their study on perceived naturalness of controllers for games with mapping. When participants played a car racing game, the authors found that a steering wheel controller was perceived as more natural than keyboard, joystick and gamepad controllers (Skalski et al., 2010). The three non-realistic control schemes did not demonstrate significantly different levels of realism. The study also determined that spatial presence did not predict game enjoyment, contrary to the authors' hypothesis; however, controller naturalness was a predictor of both spatial presence *and* game enjoyment (Skalski et al., 2010). In summary, controller naturalness improves the game experience in two ways: it aids recall of mental models, increasing spatial presence; and it increases game enjoyment. These findings reinforce the intuitive assumption that the more realistically a controller mimics a video game, the more realistic the experience will feel, and the more enjoyable it will be.

McGloin & Farrar (2011) built on the preceding research, studying the link between video game controller naturalness, spatial presence, and perceived realism. Their study measured the enjoyment of a tennis video game while using the PlayStation DualShock 3 controller (thumbstick design; no natural mapping to playing tennis) versus the Nintendo Wii Remote (motion-based; natural mapping to swinging a tennis racket). Their results demonstrated that the Wii Remote's mapping scheme was more natural than the DualShock 3, leading spatial presence and perceived realism to be reported higher when using the Wii Remote (McGloin & Farrar, 2011). These results were stronger than those of Skalski et al. (2010), whose studies could not determine whether or not perceived realism increased or not with natural controller mappings.

Pointing Performance

The second dimension of controller quality is *pointing performance*, or the degree to which a controller allows the player to quickly and accurately convey pointing input. Gamers who want to perform at the highest standard possible need to possess the mental skill to play a game successfully, as well as the physical skill to make intricate maneuvers with their controller. The extent to which a controller aids or gets in the way of these intricate maneuvers is paramount in competitive play. Speed and accuracy of controller input can be summarized by the concept of *throughput*: technically a measure of information in bits per second, but generally a succinct measurement of speed and accuracy of movement performance. Controllers that offer the maximum possible throughput will offer the best precision and accuracy for players, therefore being preferred for contexts where maximum playing performance is desired.

Natapov, Castellucci & MacKenzie (2009) studied the throughput of pointing tasks with three different styles of controllers: the standard computer mouse, the Nintendo Wii Remote, and the Nintendo Wii Classic Controller. Each style uses a different mechanism to move a pointer: the

mouse tracks small wrist movements on a flat surface, the Wii Remote tracks larger arm and wrist movements pointing towards a screen, and the Classic Controller uses omnidirectional thumbsticks. They used an experimental design based on *Fitts' law*, a mathematical relationship that predicts the time to reach a target given its size and distance away from a starting point. Specifically, the ISO 9241-9 standard was used for a multi-directional tapping task to calculate throughput in bits per second (Natapov et al., 2009). It was found that the mouse outperformed both of the game controllers in the pointing task, performing 31.5% better than the Wii Remote and 60.8% better than the Classic Controller (Natapov et al., 2009). Furthermore, the mouse demonstrated the lowest error rate. The authors concluded that thumbsticks are not especially well-suited for point-select tasks, despite their presence on many modern controllers (Natapov et al., 2009).

Klochek & MacKenzie (2006) presented five new performance metrics to help quantify the differences in throughput between game controllers. In doing so, they provided greater insight into why the mouse is generally measured to be more precise than the thumbstick controller. Interestingly, in their own study, they observed that both the mouse and the thumbstick controller could track a target in 3D space equally well. However, the mouse's greater movement acceleration allowed users to *correct errors more readily*, leading to better overall tracking performance (Klochek & MacKenzie, 2006). The authors justified this by explaining that enacting a large acceleration of a short duration is especially difficult with a thumbstick, requiring quick movement away from, and then back to, the neutral resting point of the thumbstick (Klochek & MacKenzie, 2006). The mouse's comparatively high acceleration and lack of default resting position made this task easier.

Comfort

The third dimension of controller quality is *comfort*, or the degree to which a controller has a practical shape and button layout. Controllers are often used for hours at a time, and therefore maximum ergonomic sensibility will lead to greater enjoyment and less fatigue. Several factors affect a controller's overall ergonomic quality, such as the naturalness of its shape, its weight, and the ability to reach as many functions of the controller as possible without changing grip. Unlike the previous section, which covered performance of a single pointing mechanism, this section covers performance of larger controller systems, when the shape and button layout of a controller begin to interact.

Brown & MacKenzie (2013) studied the relationship between game controller usability and hand size. They compared the Xbox 360 controller, the PlayStation DualShock 3 controller, and the Wii Remote with Nunchuk attachment. The study focused on the number of discrete hand movements necessary to reach buttons on the controller. Hand movements were inversely proportional to hand size; i.e. participants with larger hands could reach more of the buttons without adjusting their grip. The Wii Remote's unconventional remote design led it require the highest mean of hand movements at 4.8, while the Xbox 360 controller required 2.4 and the DualShock 3 required 2.0 (Brown & MacKenzie, 2013). The Xbox 360 controller yielded the strongest correlation between hand movements and hand size, which may be due to its slightly larger size. Though they were not able to demonstrate that this usability affected preference for one controller versus another, they demonstrated that for ease of use, controllers should be designed with button reachability in mind (Brown & MacKenzie, 2013). This finding brings to mind Microsoft's original Xbox controller from 2001, which was significantly larger than other controllers on the market, requiring large hands to operate effectively. Intended to target a grown-

up market, it was received poorly and soon replaced with the Xbox Controller S, a smaller version of the same controller that became the shape foundation for the Xbox 360 and Xbox One controllers (Mabry & Jackson, 2013).

Kissinger & Morelli (2015) examined the Ouya micro-console controller, which is designed with a built-in touchpad at the center of the controller. The Ouya runs a modified version of the Android mobile operating system, so the touchpad exists largely to provide compatibility for Android games requiring touchscreen interaction. The purpose of the study was to see if the touchpad provided a useful avenue for user input. The controller was measured in a throughput task, where its thumbstick had a measured throughput of 1.33 bits per second (bps), and its touchpad had a throughput of 0.65 or 0.38bps, depending on whether it was used in a mouse-like or mobile application-like context (Kissinger and Morelli, 2015). These figures of touchpad throughput are roughly an order of magnitude lower than the mouse throughput figures of Natapov et al. (2009). This indicates that the Ouya controller's touchpad provides little ergonomic benefit: it is less reachable than the thumbsticks, and it offers significantly lower throughput. Using the touchpad reduces controller comfort.

Kissinger & Morelli (2015) also measured the DualShock 4 controller in an ISO 9241-9 throughput task. Usage of the touchpad was compared when using the index finger versus using the thumb. It was found that the index finger offered significantly better throughput than thumb control, but throughput still ranged between just 0.49 and 0.65bps (Kissinger and Morelli, 2015). In the case of both the Ouya controller and the DualShock 4, the touchpads are positioned to be accessible by only the user's thumbs. This is a curious ergonomic choice, given that index finger navigation is typical for computer touchpads. This study indicates that touchpads on controllers may provide compatibility for touch-centric games, but thumb navigation severely hampers their

ergonomic effectiveness. If menus and games choose to use *require* use of the touchpad, it will be a slow and unnatural process for the player.

Discussion

Based on these findings, there is no single controller that is ideal for player enjoyment. Rather, it is clear that controller design must be domain-specific for players to find maximum satisfaction with their experience. Regarding naturalness, it is clear that wherever possible, more natural control schemes are preferable for immersion. Regarding pointing performance, the computer mouse offers the best throughput, and thumbstick controllers offer the worst. Finally, regarding comfort, core controller functions should be easily accessible with minimal change in grip.

Insight gleaned from this research is conflicting. For a first-person shooting game, for example, the realism argument suggests that a Wii Remote would lead to greater enjoyment than a computer mouse, as its motion tracking more closely approximates aiming and shooting a gun. However, the throughput argument would recommend the mouse for highest possible precision. The three identified dimensions of controller quality are not always reconcilable. It is often not possible to satisfy all with one controller.

There is a dominance of thumbstick controllers in modern gaming, with each of the three major current-generation video game consoles sporting the same basic layout on its standard controller. It is easy to argue for the practical ergonomics of the thumbstick controller. It is handheld, rather than requiring a hard surface like a keyboard and mouse. Whereas the keyboard and mouse begets sitting upright with arms resting at a comfortable height, thumbstick controllers can be easily held and operated while standing, sitting or laying down. Similarly, motion controls like the Wii Remote expect a lot from the player, often forcing the player to stand up and play at

least a few feet away from his or her television. The thumbstick controller is also tailored to versatile gaming, because unlike the keyboard and mouse, it was designed with gaming in mind. Features like thumbsticks and triggers offer pressure-sensitive input, a useful feature for many game genres.

Even though the thumbstick controller doesn't excel in every dimension, it is clear that ergonomic convenience and overall control neutrality is most important for a mass-market gaming console. However, there are still add-on products available that bring in the qualities of other control styles. Microsoft offers the second-generation Kinect camera as an accessory to the Xbox One, allowing for gesture-based control in supported games. In fact, the camera was originally bundled in with the console, but the combined price proved too high for many consumers, leading Microsoft to separate the two products so that the console could be purchased at a lower price (Kohler, 2014). Evidently, gesture-based control was not enough of a draw for the mass market to offset the price of entry. Also available for the Xbox One is the Xbox Elite Wireless Controller, a controller costing close to three times the price of a standard thumbstick controller. In effect, this controller promises serious players greater throughput, with customizable weights and thumbstick sensitivity (Orland, 2015). It is evident that Microsoft has acknowledged the importance of naturalness and precision in controller design, but it is not surprising that these options have been relegated to accessory status.

This paper only examined a small fraction of relevant research concerning video game controller ergonomics. There are many more attributes to investigate, such as individual preference for controllers, ergonomic design's impact on hand fatigue, and the impact of VR environments on naturalness, perceived realism and game enjoyment.

Conclusion

Video game quality is heavily influenced by the ease of user control, allowing the player to enjoy the game to the highest degree. As consumer technology becomes cheaper, smaller, and more powerful, it will be easier than ever for platforms to make unique and elaborate control schemes available to players. Where possible, video games should be designed with a certain control scheme in mind to increase the likelihood that the game is an enjoyable experience. The reverse is true as well: new controllers should be designed to maximize their effectiveness in one or more of the three major use dimensions: naturalness, pointing performance, and ergonomic usability.

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