A Critical Review of Video Game Controller Designs

Serefraz Akyaman and Ekrem Cem Alppay

Abstract The game understanding has changed shape according to the possibilities and needs of the digital age and gained a digital structure and penetrated to our homes and even our pockets. Increasing the rate of involvement of games in our daily lives has also provided diversification of the ways people play games. There are many computer-based platforms and game types that meet different game needs. Each platform brings with it various peripheral devices. Considering that the main purpose of the game is to enjoy, it is also important to discuss the designs of the products in question for the experience to be gained. Among the physical peripherals, controllers stand out as a remarkable area in terms of product design due to their visual and tactile (sometimes auditory) features and diversity. In this research, video game controllers discussed in terms of user needs, expectations, and academic researchers' dimensions such as natural interaction style or dimensionality. In addition to the mouse and keyboard, the current game consoles, VR game platforms, and some wearable controllers examined in the study. Also, the concepts used by users and researchers in evaluating control devices compiled and points that overlap with each other interpreted. The evaluation dimensions, which were deemed incomplete in both views, are expressed. The study, as a result, revealed the multidimensionality of the game controllers and the difficulty of making a complete comparison of the features of all the controllers.

Keywords Video games · Game controllers · Player experience

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1 Introduction

In the last few decades, digital games have become a common part of the entertainment, consumer culture, and people's daily lives. Computers, which are the critical elements of digital games and which further enrich the ability to play and entertain for both gaming and business-oriented devices due to their ability to perceive, interpret, and communicate with the environment, have managed to revolutionize the gaming area as well as in all other areas in the society [1].

Increasing the rate of involvement of games in our daily lives has also enabled the diversification of the ways people play games [2]. There are many different computer-based platforms and game types that meet different game needs—the growth and diversification in the game market progress in parallel with technological developments [3]. In particular, the development of graphics and processor technologies has an impact on the gaming industry. In addition to this, the act of playing the game is constantly changing by looking at the variation in the way of controlling the game through the control devices' designs. This study aims to make a general evaluation of video game controllers.

There are two research questions explored in this study: (1) What are the relevant dimensions of video game controllers as seen by players; and (2) What dimensions do researchers use to evaluate control devices? In this context, the main focus is to evaluate game control devices to discuss product features. As a result of this analysis, it is aimed to present a set of evaluation criteria in order to evaluate a game control interface.

2 Video Games and Human–Computer Interaction

Besides the social, cultural, economic, political, and technological factors, Newman [4, 5] states that video games are worth studying for only three features: the size of the video game industry, the popularity of video games, and the human–computer interaction in video games.

The environment where (video) gaming interaction typically occurs is called the user interface. The user interface acts as a translator between application and user semantics [6]. In the context of the game, user interfaces are called the way players interact with the game and get feedback on their interactions [4] through input (controller) and output (display) devices.

The realization of the game in the modern game layout (video games), is now dependent on the inter-layer relationship, which includes the world of the game and the way it designed, our perception of this world as a player (user) and the processes of controlling the game world. Video games reach large masses, and especially when it comes to popular games, the same games are played on very similar screens. If we consider the game interface that turns into shape, aside from the fiction or design of the game, playability has become more and more critical. In such a situation,

to establish the relationship between the game layers, the interfaces become more important. Moreover, the relationship of the control or user input devices (which is related to our ability to play) to the human being begins to turn into a point that needs to emphasize.

Video games have been delivered to users through many different platforms since their emergence. Each platform has its technology, physical peripherals (such as display, controller), and features. These different platforms are listed by Wolf [7] as mainframe computer games, coin or token operated arcade video games, home video game systems, portable handheld games, and home computer games. Although basically, every platform uses computer infrastructure, computers differ from other platforms because their purpose is not just gaming. In addition to these platforms, the development of internet technology enables the emergence of new cloud game systems such as Google Stadia. Additionally, depending on the video game classifications, it is possible to see specialized controllers or accessory designs. For example, there are steering wheel controllers for only racing games, or there are tennis rackets, bow, and baseball bat-shaped accessories for sports games.

Over time, companies have diversified their controllers on dimensions such as control type (such as directional, gestural), the way of holding (such as one hand, two hands, the need to position the unit on the floor), the way of wearing (such as on the head, arm or foot), ability to move (3DoF, 6DoF, 9DoF). Variables such as gameplay time, user characteristics, comfortable and easy use have led the control units to develop continuously. While simple mechanisms used in the designs of the first control units, today's devices have state-of-the-art motion-sensing sensors [8]. With the inclusion of wearable technologies in the sector, the control unit, and the way it controls are irreversibly changed.

3 Game Controllers

The games vary in areas such as the graphic features they use, the design of the game, and the control dimensions required. To play the game, the player must take some action. Control interfaces that mediate this playing action constitute a common point of the games. Almost every game platform produces controllers with different shapes and features, which can be customized mechanically or physically. Also, the manufacturers' design process of control devices is an issue to compete with each other.

Game controllers are input devices that aim to transfer user commands appropriately mapped to the game mechanics for manipulating the game environment. According to Crick's [9] definition controller is "the fundamental aspect that allows a video game player agency in a virtual world is, of course, the control device—allowing the player to act directly on and in that world as an extension of the player's body". These gaming peripherals have seen as an essential element that has an impact on the gaming experience. Game controllers create a layer in the virtual game world and make sense within the framework of game mechanics. Also, the controllers create

a layer in the real world for the user in terms of their physical properties and also create an interface for interaction with the game.

Many studies show that the game controllers' hardware and software components affect the way the game plays, the pleasure obtained from the game, the performance of the game, and engagement to the game [8, 10–16]. These studies are in the context of the user experience, which defined as "focusing on the experience resulting from the interaction with products" [17], which included in the field of human–machine interaction. However, in-game research, the term "player experience" (a.k.a gamer experience/gameplay experience) is used in a more specialized subform. While academic researchers use certain features in their studies, players make comparisons according to their own needs and expectations. This study aims to reveal the dimensions in which game controllers are evaluated from both perspectives and contribute to creating the most comprehensive game controller evaluation set possible.

4 Method and Scope

In the frame of research questions of this work, we decided to conduct descriptive research. A content analysis approach was considered appropriate within the design perspective to explore research questions.

In addition to the standard controllers and computer keyboard and mouse of consoles in today's market, the controllers of VR platforms also included in the study. Additionally, some wearable devices that allow playing in more than one type of game also examined.

For the first research question, user reviews and customer questions and answers section text on Amazon.com analyzed, and words of frequently pronounced characteristics identified. Controllers are classified according to these characteristics and evaluated accordingly. This question aims to discuss dimensions as the expectations of users from the product, the features they are satisfied with and dissatisfied, or the dimensions affecting the purchase decisions. Also, these dimensions can be useful when designing a new controller.

A literature review was conducted to answer the second research question. We included studies that compare multiple controllers into this research. This question aims to reveal the approaches in the evaluation of existing products by researchers.

For conducting this research content analysis method has selected. Content analysis, a tool for performing descriptive research is "a technique for examining information, or content, in written or symbolic material (e.g., pictures, movies, song lyrics)" [17].

The determined body of material to analyze is a user review and question and answers text of the game controllers on Amazon.com. Frequency analysis carried out to reveal how often the descriptive words or themes used in the texts examined.

5 Analysis

5.1 Controller Review Dimensions from Content Analysis

In the content analysis section that constitutes the first part of the study, game controllers sold on the Amazon.com website were examined. Among these devices, the products with the highest evaluation rate were chosen by the users because of the large number of mice and keyboards used in PC games. In the game consoles and VR game platforms, while controllers evaluated, the original products of the platform manufacturer companies selected, third-party manufacturers not included in the evaluation. Wearable devices also selected on Amazon.com based on the amount of sale and user evaluation. Control devices belonging to the latest platform were selected (see Table 1).

The contents of the texts in the question and answer and user reviews sections for the selected game controllers are analyzed, and frequently used specs were listed (see Fig. 1). According to the Fig. 1, compatibility is the most critical issue among gaming platforms, games, and accessories. "Compatibility" includes game, platform, and additional gaming related equipment such as headphones. "Compatibility with accessories" include additional physical parts shapes as wheels, tennis rackets or guns. Secondly, the battery life of controllers is one of the most concerning conditions for wireless controllers. Thirdly precision is significant issues for users. We grouped

Table 1 Game controllers selected to analyze

Keyboard and mouse	Gamepads	Motion controllers	VR controllers	Adapatale controllers	Wearable controllers
	• PS dualshock 4	• PS move	• PS move	• 3DRudder	
	• Microsoft Xbox one			• MXbox adapatable	
	• Nintendo switch Joy-Con & Pro	• Nintendo Joy-Con			
	• Steam		• Steam value index		• CaptoGlove
			• HTC VIVE and Cosmos and focus		• Hi5 glove
			• Oculus touch and Go Stadia		• Bcon
			• Samsung gear VR		• Tilted

Source Authors

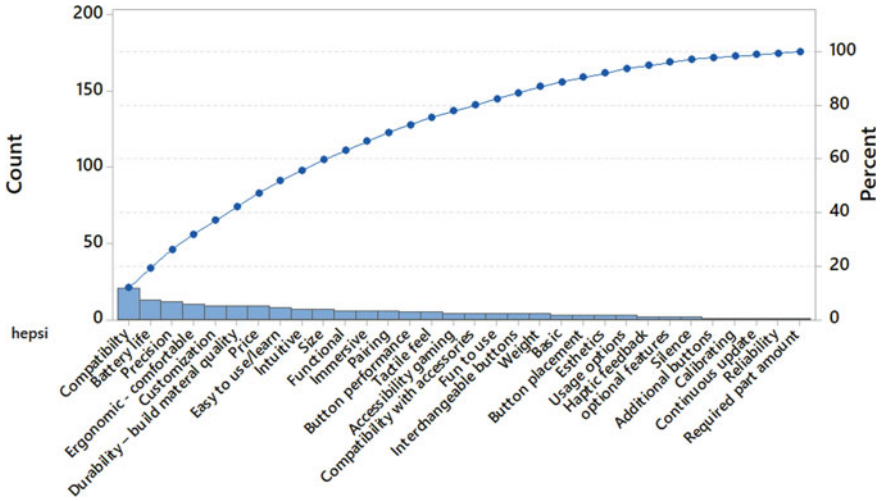

Fig. 1 Frequently used specs in the texts of questions and answers and reviews of selected controllers. *Source* Authors

all 32 keywords into four: Usability, physical specifications, other specifications, and experience related issues (See. Table 2).

According to Table 2, physical specification related comments are the most common in user reviews. In this group, compatibility, battery life, comfort and durability related specifications of controllers are the most interpreted dimensions. Secondly, in usability related review group, the most commented issues are ergonomics, precision, ease of use and learn, and intuitiveness. Thirdly, users comment about gaming experience related features such as comfort, intuitiveness, immersion and compatibility with accessories. As an economic dimension, price is another essential aspect for controller selection especially if the controller widely compatible with other platforms.

Mostly some adaptor hardware (game controller converter products) or software needed to make controllers compatible with other gaming platforms. Compatibility may be limited to some game types or games. For example, Tilted wearable controller can be used with consoles but work only games that support mouse and keyboard. Game controllers have listed in Fig. 2 according to their compatibility with other game platforms. The circle plot was generated with Circos [18]. As a reminder, for full compatibility, both platform's control requirements (such as gyroscope, accelerometer), and capabilities should fit.

Besides the compatibility with other gaming platforms, controllers can be compatible with certain game types. For example, racing wheels are suitable for racing games, or tennis racket shape controllers or accessories are meaningful for playing tennis, table tennis, or badminton games. Gun accessories to original controllers or new products like PS VR Aim Gun are usable in First Person Shooter (FPS) games, or guitar shape controllers can be used only in rhythm games like Guitar Hero (2005).

Table 2 Descriptive words grouped according to the terms with which they relate

Usability	Physical specifications	Other specifications	Experience related issues
• Accessibility gaming	• Additional buttons	• Basic	• Compatibility with accessorizes
	• Battery life	• Calibrating	
• Additional buttons	• Button placement	• Compatibility	• Ergonomic-comfortable
	• Compatibility	• Customization	
• Basic	• Compatibility with accessorizes	• Optional features	• Haptic feedback
• Button placement		• Pairing	• Immersion
• Compatibility with accessorizes	• Customization	• Update	• Intuitiveness
	• Durability-build material quality	• Price	• Silence
• Easy to use/learn			• Tactile feel
• Ergonomic -comfortable	• Ergonomic-comfortable		
	• Esthetics		
• Fun to use	• Haptic feedback		
• Functional	• Interchangeable buttons		
• Intuitiveness	• Silence		
• Precision	• Size		
• Reliability	• Tactile feel		
• Usage options	• Weight		
	• Required part amount		

Source Authors

They are specifically designed to be formally similar to non-game elements on which the game is based on [19].

There are limited amounts of controllers designed for only one type of game, but they have the advantage of feedback options from the point of immersive experience. Such controllers defined as realistic tangible natural mapped devices in the classification made according to the mapping style [11].

On the other hand, non-electronic accessories can simulate real experience on a limited degree, especially for motion supported games. For example, for the PS Dualshock4 controller, there are additional steering wheel-shaped attachments. For Nintendo switch joy-con and PS Move controllers, there are accessories such as tennis racket, steering wheel, bow, gun-shaped in the market.

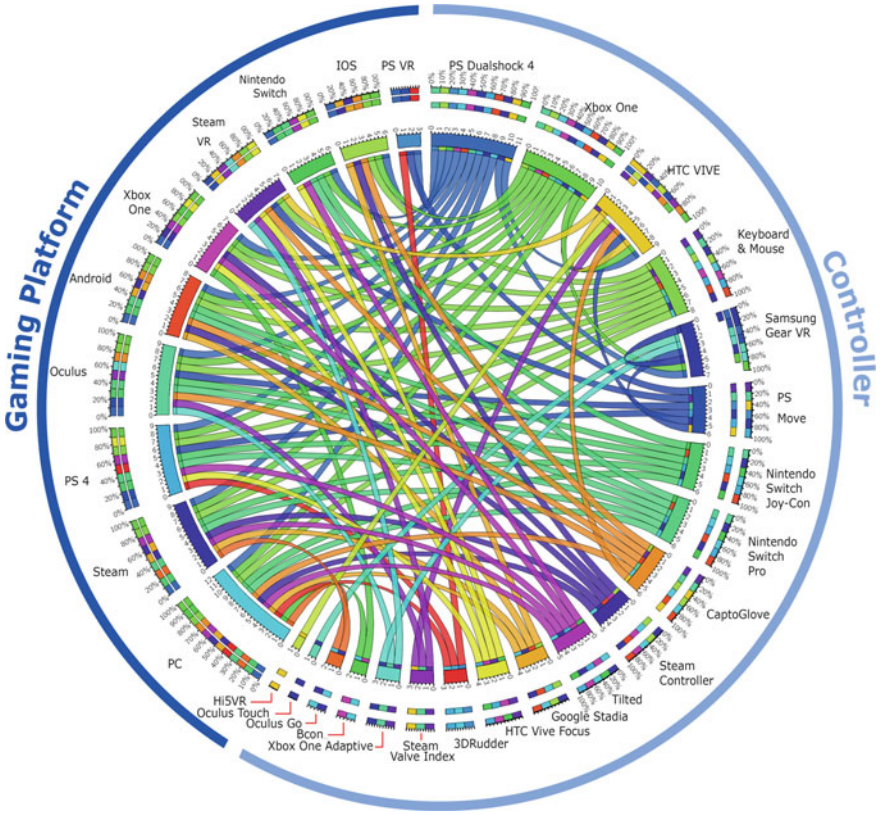

Fig. 2 Cross compatibility of video game controllers between gaming platforms. *Source* Authors

5.2 Controller Review Dimensions from Literature

Current research compare game controllers by naturalness [10, 13, 20–23], usability [24], control schemes [25], control techniques [26], realism level of the controller [27], in terms of semiotics [19], user performance [28–30], and compare existing controllers with prototypes designed [31, 32].

On the other hand, a large number of researches also focuses on the impact of controllers on player experience related terms as immersion, presence, engagement, enjoyment, flow, positive and negative affect [13, 19, 21, 25, 32–34].

The primary dimension for classification of the game controller made from *an intuitive interaction perspective* in related researches. Intuition is a situation involving the information processing processes applied in that product/interface rather than being a feature of a product or interface [35]. Therefore, intuition is an essential element of communication and interface design when controlling and using technological devices [36]. In the case of game controllers, "*natural mapping*" term appears. The most basic way of manipulating the controllers more naturally is to

make a match between the directions used to interact with a controller and the results in the world or on the screen [11]. Steuer [37] defines the term mapping as "the ability of a system to map its controls to changes in the mediated environment naturally and predictably." Natural mapping uses physical analogies and cultural information to help users understand how to control devices [38]. The naturally mapped user interfaces offer the possibility to control the game mechanics more naturally instead of mastering the controller. For example, it is easier to remember to pull the trigger of the gun-shaped controller instead of remembering which key to press to shoot. Alternatively, instead of the key combination required to make a shot in a tennis game, it is enough to shake the motion controller like hitting the ball coming in that direction.

There are four different types of game controllers according to their mapping style: (1) directional natural mapping, (2) kinesic natural mapping (3) incomplete tangible natural mapping, and (4) realistic tangible natural mapping [16, 17, 27]. Birk and Mandryk [14], similarly classified controllers as traditional (e.g., Xbox GamePad), positional (e.g., PlayStation Move), and gestural (e.g., Microsoft Kinect) in their research.

The most basic way for controllers to be mapped more naturally is to establish a relationship between the directions used to interact with a controller and the results on the world or the screen [11]. This direction based control-interface mapping is called directional natural mapping. This relationship helps to achieve a real-world response through physical control, such as moving a bucket of an excavator machine and getting a virtual result from a virtual control interface, such as switching pictures on a smartphone.

Kinesic naturally mapped devices correspond to real-life actions and the movement of all or limbs of the human body with the game world, unlike controlling using handheld keys or analog sticks [11].

The main feature of the third group, which is called incomplete tangible natural mapping, is that they partially simulate the feeling that the real situation will give [11]. For example, using the Nintendo Joy-Con controller as a tennis racket in a tennis game is to associate the virtual object with a physical object as an imitation. They are called incomplete because the objects they substitute do not have precise features such as shape, weight, texture, haptic feedback [11].

The realistic tangible natural mapping defined as the state of simulating real-life feelings and feedback in a very similar way at visual, formal, and functional levels [11]. An example of the products included in this group today is the steering wheel sets used in racing games.

According to this classifications, gamepads, keyboard, and mouse listed under directional mapping. In this group, the Nintendo Joy-Con and Ps Move controller classified as incomplete tangible natural mapped devices because of the motion control abilities. VR platforms controllers other than gamepads also classified as incomplete tangible natural mapped devices.

From the other perspective, Natapov [39] categorizes game controllers as detached, immersive, and hybrid. Detached controllers defined as traditional and work as input message creators. Immersive controllers help gamers to engage in the

game by enhancing the enjoyment. Hybrids, on the other hand, can be defined as controllers with immersive and detached features.

The control complexity of game controllers is also a practical dimension in classification. Control Dimensionality (CD) is used to grade a control mechanism by complexity [40]. CD is used for numeric comparison of video games, but it can also be used to see the maximum controller dimensionality of a controller (See. 42). Controllers have control abilities through parts like buttons, sticks, pedals, triggers, thumbs, or sensors. It is expected that the CD of a controller should coincide with the game mechanics. It is also possible to use the CD evaluation to classify player tolerances (See. 41).

According to Bateman and Boon [40], to calculate the CD, the "freedom of move" level should be defined first. If the game or controller can do only left and right moves (one-dimension), then CD = 1. If mechanics allow moving left–right, up-down (two dimensions), then CD = 2. If one can move left–right, up-down, in–out (three dimensions) in a game, then CD = 3. After that, as a secondary dimension, should add points according to:

- As an additional movement dimension (such as accelerate-brake, controlling the speed of time), add 1 point.
- As an embedded or hidden action (such as crouch, attack, jump), add 0.5 points.

However, this calculation method may include some subjectivity [41].

6 Discussion and Conclusion

Users evaluate existing game controllers based on the problems they face during their experience and their expectations from them. As revealed in the analysis, user requests appear to be directly related to compatibility, price, performance, battery life, and comfort. Additionally, as the natural mapping degrees of the game controllers increase, the frequency of expressions such as "intuitive," "fun to use," "easy to use, and easy to learn" increases in the review texts. This point corresponds to the focus of the studies in the literature. We observed that users tend to compare the same types of controllers when expressing their opinions in similar games, especially the directional mapped controllers in the form of gamepads compared with each other. There are many comments, especially on price and compatibility issues, especially in games that show both directional and incomplete tangible natural mapping features such as Nintendo Joy-con. There is no comparison of these two types of usage observed between different game types. However, there are some comparisons of the directional mapped version with other gamepads in the comments.

The vast majority of video game-related studies are on the design and usability of the video game itself. There is relatively little work on the peripheral elements of the game, such as game controllers. In the reviewed studies, the game controllers have studied in two main focus: usability and experience. In the studies based on usability and performance, game controllers compared to various game types or various tasks

such as pointing. While making the evaluation, objective evaluations such as task completion time, amount of error, and subjective evaluations were made based on the comments of the players.

Similarly, at least two different types of controller comparisons made within the scope of one or more game types in studies focused on player experience. In these studies, the focus is on both game performance and enjoyment intersection. Studies also have many different evaluation tools (e.g., PENS, GExpQ, GEngQ, IEQ) created mostly based on motivation theories; the focus of evaluation differs from each other. These scales, which contain parts for evaluating the game controller, are formed in the focus of one or more terms such as immersion, presence, flow, enjoyment, competence, engagement, cognitive and emotional involvement. Moreover, they are limited in evaluating the control action independent of the game's design.

A comprehensive comparison is only possible by specifying and grouping the characteristics of the controller variants. However, this grouping may also fail to cover and evaluate all of the control devices. For example, we observed that wearable devices used in-game control were not included in the classifications. There is no criticism study from the design perspective in terms of the relationship with the body and product.

This research revealed that the multidimensionality of the game controllers and the difficulty of making a complete comparison of the features of all the controllers. Besides, looking at neither the size and availability of control devices nor the perspective of control schemes or natural match levels allows for a general assessment of the controller. On the other hand, comparisons made in a single game type also give results based on the game type. Evaluating the controllers in games that require different dimensionality will give us a more holistic understanding. It will be beneficial to make a more general evaluation to include design dimensions related to formal features and ergonomics in research.

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