

The Ergonomic Development of Video Game Controllers

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Abstract

Video game controllers are often the primary input devices when playing video games on a myriad of consoles and systems. Many games are sometimes entirely shaped around a controller which makes the controllers paramount to a user's gameplay experience. Due to the growth of the gaming industry and, by consequence, an increase in the variety of consumers, there has been an increased emphasis on the development of the ergonomics of modern video game controllers. These controllers now have to cater to a wider range of user anthropometrics and therefore manufacturers have to design their controllers in a manner that meets the anthropometric requirements for most of their potential users.

This study aimed to analyse the evolution of video game controller ergonomics due to increased focus on user anthropometric data and to validate the hypothesis that these ergonomics have improved with successive generations of video game hardware. It has analysed and compared the key ergonomic features of the SEGA Genesis, Xbox, Xbox 360, and PS4 controllers to observe trends in their development, covering a range of 25 years of controller development.

This study compared the dimensions of the key ergonomic features of the four controllers to ideal anthropometric values that have been standardised for use in other handheld devices such as TV remotes or machinery controls. Based on the findings, it arrived at a conclusion about the ergonomic viability of video game controllers as input devices for other purposes apart from being specialised for the niche purpose of gaming.

Keywords: Ergonomics; Anthropometrics; Video game controllers; Gaming; Input devices

Introduction

The video game industry is considered one of the fastest developing industries, growing four times faster than the US economy [1]. The controller is one of the most essential products in the video game industry as it acts as the primary input device for a variety of gaming consoles.

In its infancy, the video game industry produced some very uncomfortable controllers between the 80s to the early 2000s, which were infamous for their awkward designs (Figure 1). The Original Xbox controller in particular was designed to be too large for the average user, making it difficult to reach certain buttons [2].

It can be hypothesised that, in the past, controller manufacturers did not fully take the anthropometrics of their users into account. However, due to the video game industry becoming more mainstream, it became essential for manufacturers to appeal to larger consumer bases by creating controllers with improved ergonomics by adhering to industry standard dimensions used in typical handheld devices to meet their users' varied anthropometrics.

This paper has tested the hypothesis through an analysis of the ergonomic development of a variety of video game controllers over the years.

Literature Review

Although previous research related to video game controllers acknowledged their development and the key tenets of their design, little has been done to analyse exactly how user anthropometrics were used to design the shapes of these controllers to achieve improved ergonomic soundness.

Heatherly et al. [3] conducted research that acted as a summary of the history of video game controllers throughout the years, and also of the different areas of importance in controller design. It highlights that in the past controllers were specially designed for individual games and could not be adapted to play other games. The research refers to the 'Magnavox Odyssey 100', the controller used to play the classic 'pong' game, to illustrate this issue. In contrast, modern controllers such as the Xbox One, also referenced by the research, have evolved to be able to play an increased variety of games with significantly varied control schemes.

Heatherly et al. [3] research recognises the size of the controllers as one of the major challenges that manufacturers have to face to make their controllers more accessible and adaptable to allow them to be



Figure 1: The Sega Saturn controller (Left) and the original Xbox controller (Right).

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used for an increased variety of games. The research states that “the physical properties of the controller give it shape and mass, dictating how the user controls the controller. Different masses and styles can lead to different uses for the controllers.” In other words, the research highlighted the importance of the ergonomics of video game controllers and how these enable controllers to be used by a larger variety of users in more versatile ways for a vast number of distinct games. However, this research was purely qualitative in nature and did not look into exactly how the manufacturers chose the size and shape of their controllers. My study explored the quantitative aspect of controller ergonomics and how these ergonomics lent them to improve the aforementioned versatility of modern controllers.

Brown and MacKenzie [4] found that a user’s hand size affects the usability of the controller in question. This is because presently controllers are not designed to be adjustable, and must rely on their fixed design to accommodate as many users as possible. This leaves groups of users with difficulties operating certain controllers—one of the major difficulties being the ability to reach certain buttons from the natural holding position of the controller. As compared to the research by Heatherly et al., this research quantitatively analyses how user hand sizes can affect the extra movements users have to make to operate buttons that are out of their reach. Through this analysis, Brown and MacKenzie research concludes that users with large hand sizes carry out fewer hand movements and thus experience improved usability for the controller while the opposite stands for users with smaller hand sizes. This discrepancy in the usability of controllers with users of different hand sizes is what controller manufacturers are minimising by designing modern controllers with ergonomics and user anthropometrics in mind. They are developing the fixed design of their controllers in a manner that allows the controllers to comfortably accommodate more users.

It should be noted that Brown et al.’s research only looks at controllers from the previous video game hardware generation,

such as the Xbox 360, and PS3 controllers. This is important to note as there have undoubtedly been improvements in the designs of game controllers since this previous generation, which are not fairly highlighted by this research. In addition, Brown et al.’s research focuses on how user hand sizes affect controller usability rather than discussing how the usability is affected by the size and shape of the controllers. The present study brought the focus away from the user and onto the controller itself, and showcased quantitative improvements in the fixed design of controllers from older generations to the latest one.

With the growth of the gaming industry comes an increase in the size of the consumer base. Due to this growth of consumers with such varied anthropometrics, it is of utmost importance for controller manufacturers to focus on ergonomically sound designs for their controllers. Therefore, the aim of this study was to analyse how increased focus on user anthropometric data improved the ergonomics of successive controller generations [5,6].

Research Plan

Firstly, a variety of distinct controllers manufactured over different time periods throughout the growth of the gaming industry were selected for testing. Specification criteria that the controllers must meet were then developed using stipulated dimensions for certain key components of handheld devices from the anthropometric guide, ‘The Measure of Man and Woman’ by Tilley (Figure 2) [7]. It was planned that the criteria would be used for the purpose of comparing these key components of the controllers effectively.

Next, in order to test how well the controllers met the specification criteria, methods of measuring the key dimensions of the controllers were devised (Figure 3). The data collected using these methods was then compared to the specification criteria to judge the successes of the components of each controller.

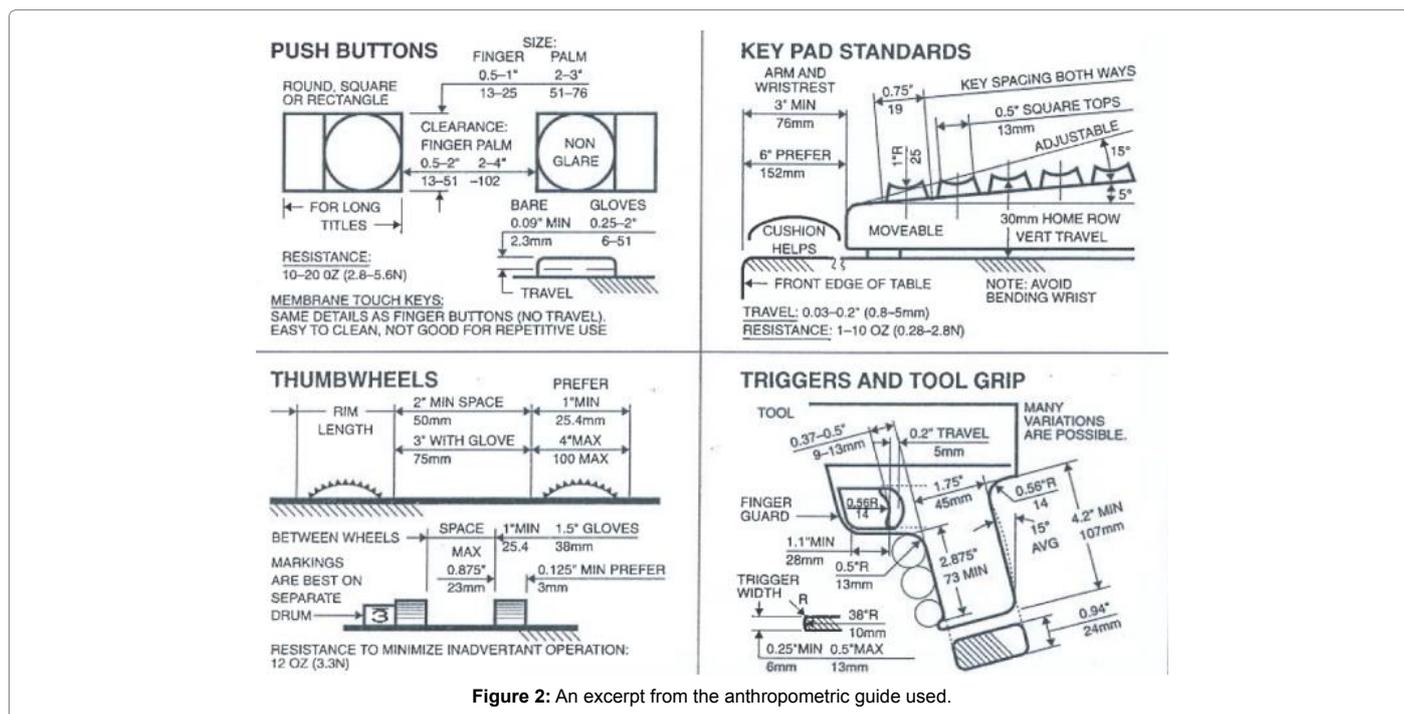


Figure 2: An excerpt from the anthropometric guide used.

The successes of each controller were analysed to observe any trends or patterns that might support the hypothesis. To further test the hypothesis, a prototype controller (Figure 4) was designed and 3D printed that meets every specification criterion perfectly. This prototype controller was also tested using the same methods used with the other controllers. Based on the combined results of the prototype and other controllers, a conclusion was drawn with regard to the accuracy of the initial hypothesis.

Controllers Tested

The data was collected from 4 controllers manufactured over different time periods over the last 25 years to test the hypothesis. To ensure that this data was unbiased, the controllers selected were from a variety of manufacturers.

This controller was designed for the SEGA Genesis. It is considered by some to be one of the greatest controllers ever created due to the flexibility it offered with its 6 button gamepad (Figure 5) [5].

This controller is a revised edition of the original Xbox controller – as suggested by the ‘S’ in its name. It was replaced as the standard controller for the original Xbox in 2003 due to its superior ergonomic qualities as compared to the older controller (Figure 6) [6].



Figure 5: SEGA genesis controller manufacturer: SEGA, Release year: 1989.

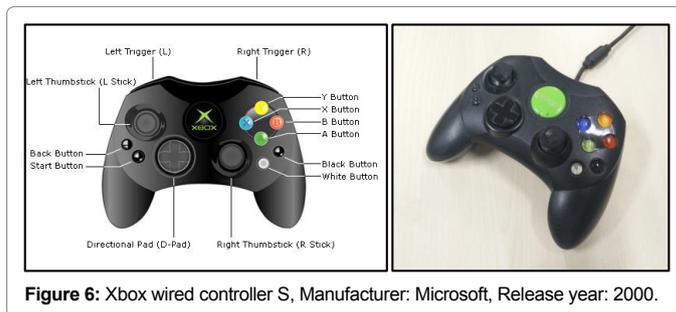


Figure 6: Xbox wired controller S, Manufacturer: Microsoft, Release year: 2000.

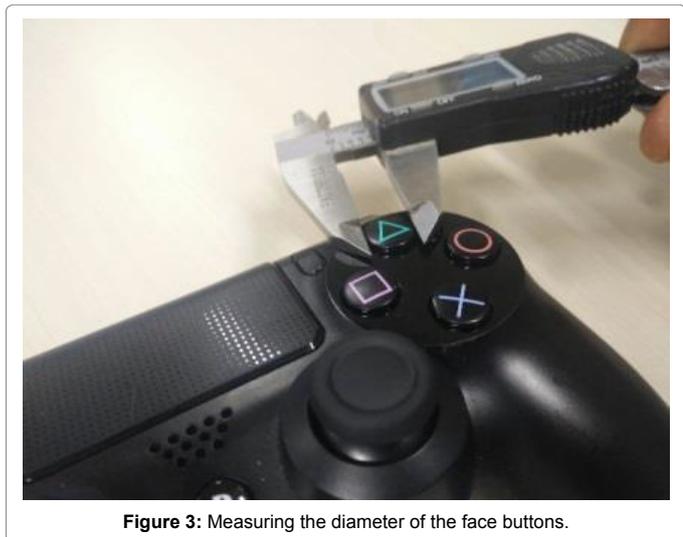


Figure 3: Measuring the diameter of the face buttons.



Figure 4: The 3D printed prototype controller.

This controller was manufactured by Microsoft specifically for the Xbox 360 console. It is often regarded as the best controller that has ever existed despite its age and has top rankings in countless surveys and articles online due to its ergonomic qualities (Figure 7).

This controller was released together with Sony’s ‘next-generation’ PS4 console. It is considered the most advanced controller ever built due to its unique features such as a 3-axis gyroscope, built-in touchpad and speakers (Figure 8).

General Components of a Controller

In this section, the major components on a standard found video game controller are labelled (Figure 9). These components will be referenced multiple times in this paper.

Specification Criteria

Normally, the anthropometrics for specific body parts of a large group of users would represent a normal distribution (Figure 10). It is evident from the figure that users with body dimensions in this case, their height that are either too small or too large represent the 5th and 95th percentile respectively, while users with average anthropometrics represent the 50th percentile. Therefore, when designing parts for a controller, it is important to note which percentile the part is being designed for to ensure the best ergonomics.

In order to compare the controllers fairly and effectively, specification criteria that tested the ergonomics of the most important parts of the controllers were created. Based on how well the parts met these criteria, any trends or patterns that could be used to test the hypothesis were observed and then analysed.

The specification criteria were based on stipulated anthropometric values derived from the book, ‘The Measure of Man and Woman’ by Tilley [7]. This book contained data on user anthropometrics and gave a range of ideal dimensions for parts such as buttons, triggers, etc. for both the 5th and 95th percentile of users. Table 1 lists the specification criteria that will be tested along with their reasons for being tested. Each

specification criterion takes an appropriate percentile into account to ensure that the part associated with the criterion is being tested to ensure the best ergonomics possible.

Methodology

The method of data collection for each specification criterion listed in the previous section will be detailed in this section. The chosen method of data collection for each criterion will also be discussed and justified below.

As most of the criteria being tested require quantitative data to be collected, multiple trials of each test will be carried out, the data from which will be averaged to reduce errors and uncertainties in the data. The data from each trial will be shown in the raw data in the appendix. For the purpose of comparing the products, a pass or fail system will be used to judge features that are required to adhere to a fixed range of anthropometric values (As stated previously, these values will be derived from the anthropometric guide, ‘The Measure of Man and Woman’). For features that require user feedback, a score based system will be adopted that the users will use to judge the appropriate features of the controllers.

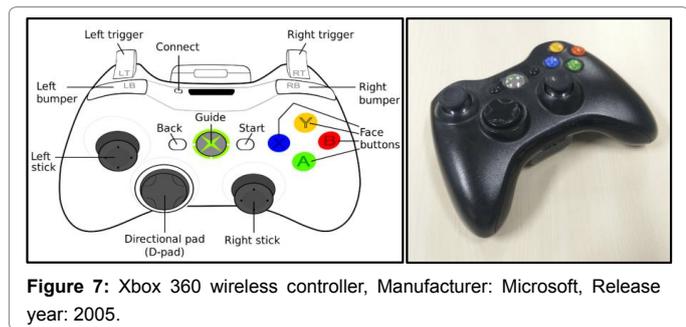


Figure 7: Xbox 360 wireless controller, Manufacturer: Microsoft, Release year: 2005.

Criterion 1

The buttons need to be large enough in width/diameter to facilitate the 95th percentile of users. This was measured using the large teeth of the Vernier calliper (Figure 11). It was ensured that the calliper lay flat against the face of the controller when measuring to negate any accidental errors that might arise if a diagonal distance was being measured instead. The widths and diameters of the face buttons, the triggers (Figure 12), the diameter of the directional pad (Figure 13) and the diameter of the tips of the analogue sticks (Figure 14) were measured using the Vernier callipers.



Figure 8: PS4 wireless controller, Manufacturer: Sony, Release year: 2013.

Criterion 2

The distance between the buttons should be large enough that they can be pressed individually by the 95th percentile of users. This was measured using the Vernier callipers (Figure 15). Instead of the large teeth, the rear teeth of the callipers were used as these allowed the distance between the buttons to be accurately measured by allowing the



Figure 9: General components of a controller.

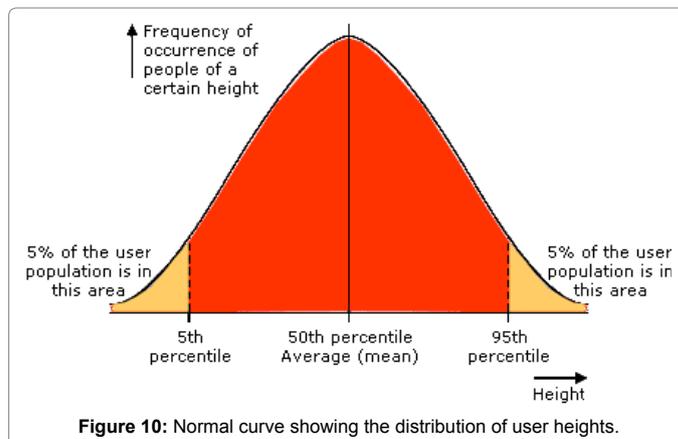


Figure 10: Normal curve showing the distribution of user heights.

No.	Criterion	Reasons for Testing
1	The buttons need to be large enough in width/diameter to facilitate the 95 th percentile of users	Users with larger fingers will not be able to press the buttons accurately if the buttons are too small for their fingers
2	The distance between the buttons should be large enough that they can be pressed individually by the 95 th percentile of users	Users with larger fingers might accidentally hit multiple buttons if they are spaced too close to each other
3	The maximum movement angle on the analogue sticks should be small enough to allow complete movement for the 5 th percentile of users	If the maximum movement angle is too large, users with smaller hands will not be able to fully extend the analogue sticks and will be unable to completely control the game
4	The force required to press the buttons or move the analogue sticks should not be too large for the 5 th percentile of users	The 5 th percentile of users might be unable to use buttons that require more force for extended periods of time without experiencing fatigue
5	The affordance [Affordance: The visual cues and feedback a device provides to allow the user to intuitively know how to use it as intended] of the controller should provide the user with ample information to use the controller as it is intended	This allows the controller to be used in a proper manner and to provide the user with a better experience

Table 1: Specification criteria.



Figure 11: Buttons width/diameter measurement with Vernier calliper.



Figure 14: Analogue sticks diameter.



Figure 12: Face button measurement.



Figure 15: Buttons space distance.



Figure 13: Diameter of the directional pad.

teeth to extend until the entire gap between the buttons was covered. Using the wrong teeth of the callipers could cause an extra extension in the callipers that would give a large value than the actual value, or using a ruler would lead to a parallax error.

Criterion 3

The maximum movement angle on the analogue sticks should be small enough to allow complete movement for the 5th percentile of users. This was measured by aligning the centre of the protractor against the centre of the analogue stick (Figure 16). Once a centre point was established, the stick was tilted to its maximum angle that was recorded using the protractor. Admittedly, this was a slightly inaccurate method of measuring this angle. To reduce inaccuracies 10 trials were taken for the measurement of this angle. These trials were averaged to minimise any errors caused by inconsistencies in the position of the protractor between each trial.

Criterion 4

The force required to press the buttons or move the analogue sticks should not be too large for the 5th percentile of users. This was

measured using a force meter which plotted its readings on a graph (Figure 17). To get accurate results, the force meter was pushed gently against the buttons and was pulled back up as soon as a reading was recorded on the graph. These readings take the form of peaks extending in the negative Y-axis on the graph. This process was repeated 10 times to form 10 peaks. The values of these peaks were averaged to reduce any random errors associated with this process. This process was carried out repeatedly to measure the forces required for the other buttons on the controllers.

Criterion 5

The affordance of the controller should provide the user with ample information to use the controller as it is intended. This data was collected by requesting a group of users with varied anthropometrics to test the controllers by gaming with them and subsequently rating each controller on a scale of 1 to 5. These users were aged between 7-30 years old, which accurately represents the demographic of gamers. These users provided qualitative information about features of the controllers such as the layout of their buttons. They were also told to comment if the features and designs of the controllers provided the users with enough information to intuitively know how to interact with the controller.

Data and Analysis

Criterion 1

The buttons need to be large enough in width/diameter to facilitate the 95th percentile of users. The buttons that will be tested under this criterion include the face buttons, D-Pad, analogue sticks, and triggers. The ideal anthropometric value for the diameters of the face buttons, D-Pad, and analogue sticks was found to be between 13 and 25 mm (Figure 18). This suggests that the minimum value for the button diameters should be at least 13 mm to facilitate users with the largest hand sizes, i.e., the 95th percentile of hand sizes. Buttons that are too small may be harder to press in-game, especially when the users are focusing on the screen and have to rely on their sense of touch to feel the location of the buttons on the controller.

Since the triggers are buttons that are not pushed down unlike the others, and are instead pulled akin to the trigger of a gun, they have to be tested using a separate anthropometric standard. The ideal width of the triggers should be between 6 and 13 mm (Figure 19).

It should be noted that the SEGA Genesis controller does not possess both triggers and analogue sticks, buttons that are a prominent feature of every modern controller. The lack of these components is considered an ergonomic flaw as it prevents users from using the controller effectively for modern games that require more input options. Hence it fails in these aspects.

Tables 2-5 compare the diameter and widths of the face buttons, D-Pads, analogue sticks, and triggers on the controllers against their respective ideal anthropometric values.

It was expected that the modern controllers would follow the ideal anthropometric values to a better extent; however Table 2 makes it evident that this is not the case. It is possible that the face buttons are deliberately made smaller for ease of transition between the buttons when users need to rapidly perform certain actions in-game.

As the D-Pad acts like a singular button that can be pressed in four different directions to generally control movement in game, it has to be relatively small in size to allow users to input quick movements. The

D-Pads of the PS4 and SEGA Genesis controllers are too large to fulfil this purpose effectively (Table 3).

In both the analogue stick and trigger tests in Tables 4 and 5, the SEGA Genesis fails due to its lack of these components. The PS4 controller fails the trigger width test as a width that is too large causes the user to exert an uneven pressure on the trigger as the force of their finger is more spread out. This can result in the trigger not being pulled back far enough to register as an input.

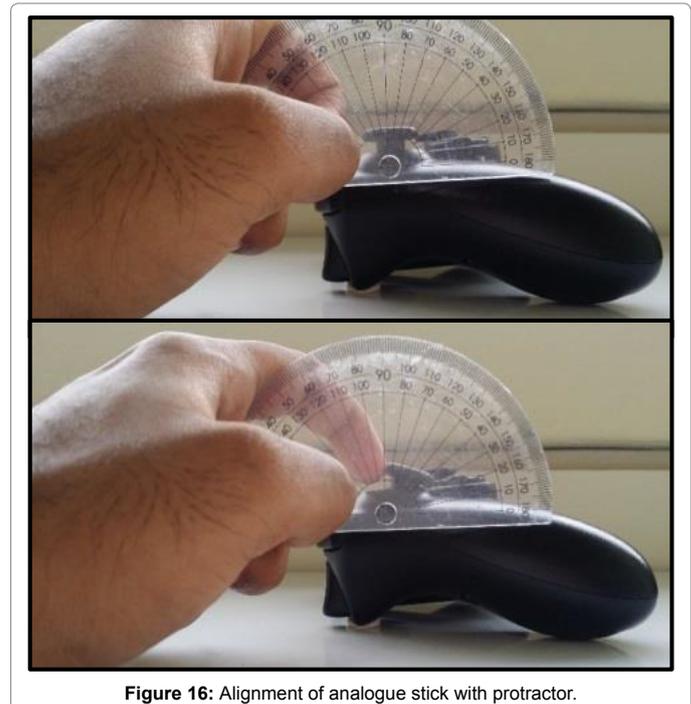


Figure 16: Alignment of analogue stick with protractor.

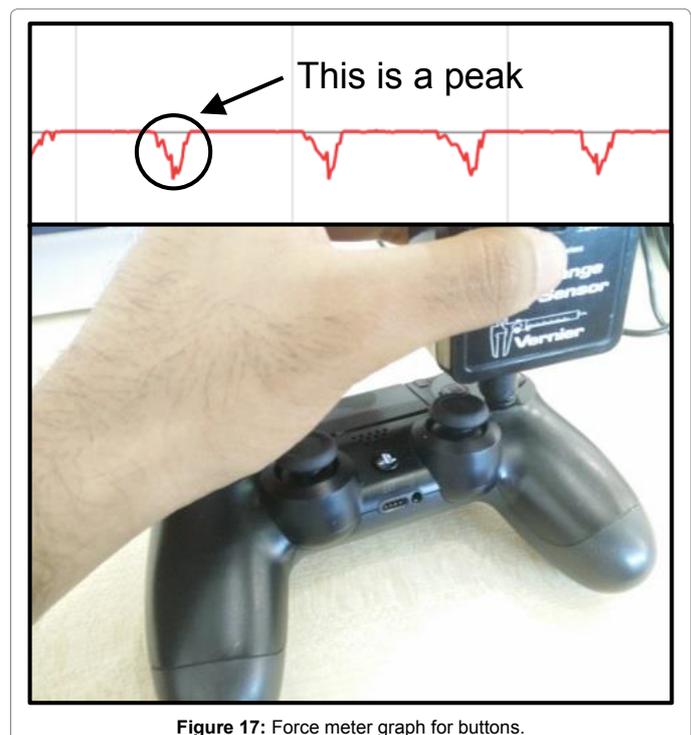


Figure 17: Force meter graph for buttons.

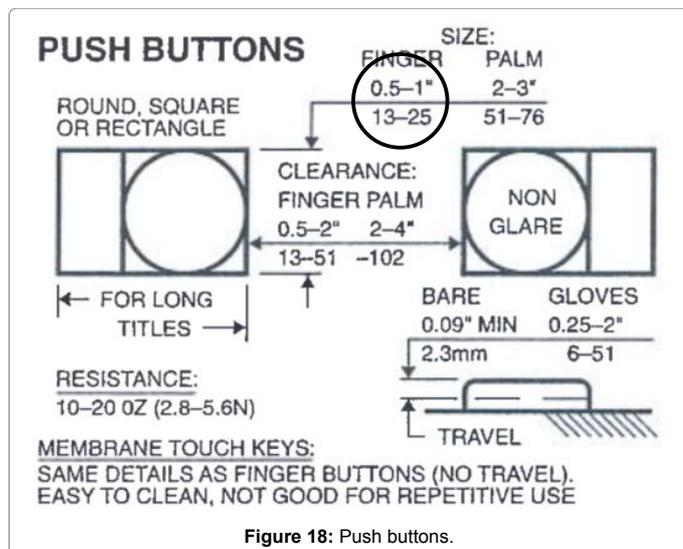


Figure 18: Push buttons.

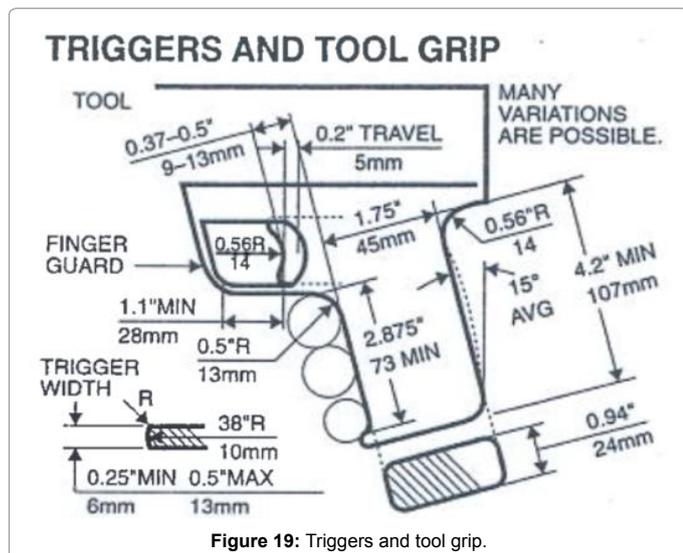


Figure 19: Triggers and tool grip.

Controller	Diameter (mm)	Ideal Diameter	Result
PS4	10.19	13-25 mm	Fail
Xbox 360	9.92		Fail
Original Xbox	10.14		Fail
SEGA Genesis	12.05		Fail

Table 2: Face button diameter.

Controller	Diameter (mm)	Ideal Diameter	Result
PS4	25.55	13-25 mm	Fail
Xbox 360	22.97		Pass
Original Xbox	23.07		Pass
SEGA Genesis	27.40		Fail

Table 3: Directional pad diameter.

Criterion 2

The distance between the buttons should be large enough that they can be pressed individually by the 95th percentile of users. The main buttons that will be tested in this criterion are the face buttons as the

Controller	Diameter (mm)	Ideal Diameter	Result
PS4	18.19	13-25 mm	Pass
Xbox 360	18.49		Pass
Original Xbox	17.63		Pass
SEGA Genesis	Not Applicable		Fail

Table 4: Analogue stick diameter.

Controller	Width (mm)	Ideal Width	Result
PS4	13.22	6-13 mm	Fail
Xbox 360	9.22		Pass
Original Xbox	9.58		Pass
SEGA Genesis	Not Applicable		Fail

Table 5: Trigger width.

rest of the buttons are spaced a sufficient distance apart. The minimum distance between the face buttons should be at least 13 mm (Figure 20). Having this clearance between the face buttons is vital as users rarely look down towards the controller while gaming, and rely purely on muscle memory to press the correct buttons. Thus, if the buttons are spaced too close to each other, users might accidentally press the wrong buttons the diameter of the buttons.

Table 6 compares the distance between the face buttons for each controller against the respective ideal anthropometric value.

It should be noted from Table 6 that although the Xbox 360 and Original Xbox controllers failed in this criterion, they came very close to the ideal anthropometric value of 13 mm. This could either be a result of random errors when measuring this distance using the Vernier callipers, or a genuine case where the distance between the buttons is, in reality, too low.

Criterion 3

The maximum movement angle on the analogue sticks should be small enough to allow complete movement for the 5th percentile of users. One of the key reasons why an analogue stick is used for in-game movement over the D-Pad is due to the increased control the analogue stick grants the users. For example, the speed of a character's movement can vary based on how far the analogue stick is pushed. The distance the sticks can be pushed is purely determined by their maximum movement angle. If this angle is too high, users with smaller hands will be unable to push the stick to its maximum value, thus hindering their gameplay experience. The ideal angle for this movement should not exceed 45° (Figure 21).

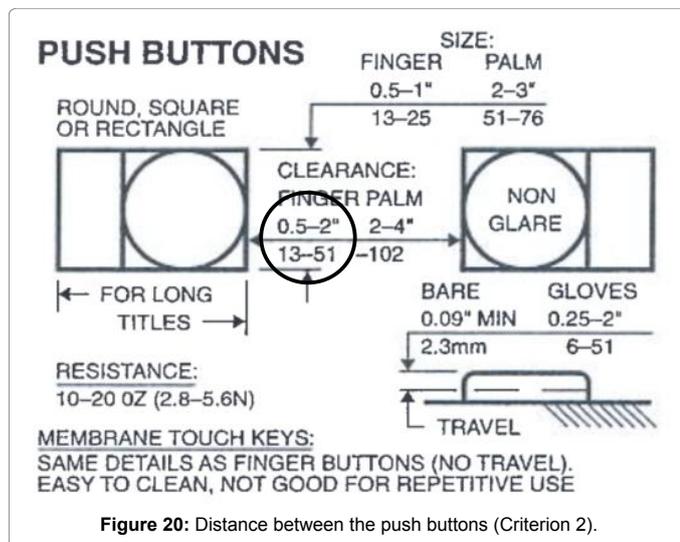
Table 7 compares the maximum movement angle of each controller's analogue sticks to the ideal anthropometric value.

As stated in Criterion 1, since the SEGA Genesis does not possess an analogue stick, it automatically fails this criterion.

Criterion 4

The force required to press the buttons or move the analogue stick should not be too large for the 5th percentile of users.

Young or physically weak users might not be able to press the controllers' buttons with ease if the force required to operate them is too high. Even if the users are able to press the buttons, they will soon face fatigue during long gaming sessions. As a worst case scenario, this fatigue could devolve into the user developing the Carpal Tunnel Syndrome.



Tables 8-10 compare the recorded values for the forces required to operate the face buttons, D-Pad, and the analogue sticks.

Although the force required to operate the face buttons of the SEGA Genesis falls under the maximum force (Table 8), it should be noted that the force required is significantly higher than that of the buttons on the other controllers. This point highlights the importance of the increased ease of operating the controller; this is something that manufacturers began to dedicate more attention to as evident by the overall reduction in the force required for the newer controller generations.

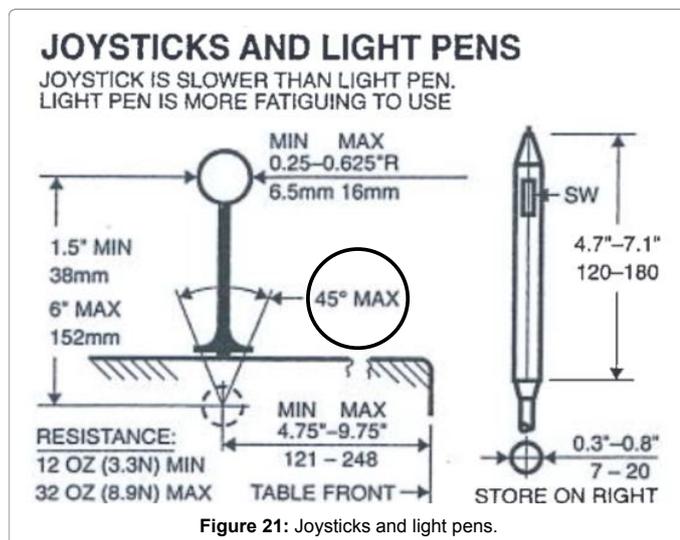
Akin to the data in Table 8, a clear trend can be identified in the data in Tables 9 and 10; the force required to operate the D-Pad and analogue sticks decreases with each successive generation of controllers.

Criterion 5

The affordance of the controller should provide the user with ample information to use the controller as it is intended.

For a controller to be ergonomically sound, not only does it have to consider the anthropometrics of its users, but it also has to consider its affordance. As stated before, the affordance of a device is the visual cues it provides to give the user enough information to intuitively use the controller as intended. As this is a qualitative form of data, feedback about the affordance of each of controller will be collected from four different users. The four users will score each controller on a scale of 1-5 for a total score of 20 points for each controller. Table 11 shows the users' scores for the controllers. Additional user comments are included in the appendix.

Table 11 presents another simple trend; the affordances of the controllers improve with each successive generation.



Controller	Force (N)	Ideal Force	Result
PS4	1.59	<5.6 N	Pass
Xbox 360	1.91		Pass
Original Xbox	1.85		Pass
SEGA Genesis	3.42		Pass

Table 8: Face button force.

Controller	Distance (mm)	Ideal Distance	Result
PS4	13.12	>13 mm	Pass
Xbox 360	12.87		Fail
Original Xbox	12.77		Fail
SEGA Genesis	4.68		Fail

Table 6: Face button distance.

Controller	Force (N)	Ideal Force	Result
PS4	2.48	<5.6 N	Pass
Xbox 360	2.94		Pass
Original Xbox	4.54		Pass
SEGA Genesis	5.12		Pass

Table 9: Directional pad force.

Controller	Maximum Angle	Ideal Distance	Result
PS4	17.41	<45°	Pass
Xbox 360	15.78		Pass
Original Xbox	17.99		Pass
SEGA Genesis	Not Applicable		Fail

Table 7: Analogue stick maximum movement angle.

Controller	Force (N)	Ideal Force	Result
PS4	1.47	<8.9 N	Pass
Xbox 360	1.69		Pass
Original Xbox	1.59		Pass
SEGA Genesis	Not Applicable		Fail

Table 10: Analogue stick force.

Figures 22 and 23 show the ideal anthropometric values for the forces that are involved in the operation of the controllers; these values have been circled in the figures. It should be noted that for all practical purposes, only the maximum force values will be considered since there is no use of a minimum value for the force as an increased ease of pushing the buttons is advantageous to the ergonomics of a controller.

Controller	User 1	User 2	User 3	User 4	Total
PS4	5	4	4	5	18
Xbox 360	4	5	3	3	15
Original Xbox	3	3	3	2	11
SEGA Genesis	3	2	1	1	7

Table 11: Controller affordance scores.

Results

Criterion 1

The buttons need to be large enough in width/diameter to facilitate the 95th percentile of users. For the D-Pad diameter, analogue stick diameter and trigger width, the controllers throughout all four generations managed to either meet the ideal anthropometric values or came extremely close to meeting the stipulated values. However, all four controllers failed to meet the stipulated values for the face button diameter. Most of the controllers fell short of the ideal value by 20% or more. Judging by this outcome, it is likely that the controllers were deliberately designed in this manner.

Criterion 2

The distance between the buttons should be large enough that they can be pressed individually by the 95th percentile of users. A clear trend can be spotted in how each successive controller generation incrementally comes closer to meeting the ideal face button distance until the newest PS4 controller finally achieves a pass. The SEGA Genesis's antiquated ergonomics become fully apparent in this criterion.

Criterion 3

The maximum movement angle on the analogue sticks should be small enough to allow complete movement for the 5th percentile of users. The ideal maximum movement angle of analogue sticks is something that all controllers bar the analogue stick-less SEGA Genesis, are able to adhere to. This might be due to the predominant usage of analogue sticks in arcade consoles and other antique controllers that has made the design of analogue sticks well-established.

Criterion 4

The force required to press the buttons or move the analogue stick should not be too large for the 5th percentile of users. The force required to press the buttons on the controller is one of, if not the primary aspect that affects the controllers' ergonomics. Hence it is relieving to see that all controllers are able to meet the ideal force requirement. A noticeable trend is that, generally, the force required to operate the buttons has gone down with each successive controller generation.

Criterion 5

The affordance of the controller should provide the user with ample information to use the controller as it is intended. The PS4 controller, the latest controller, achieved the highest total score out of all controllers in terms of their affordances. This supports the initial hypothesis by showing that controller ergonomics have most certainly improved over the years and that manufacturers are successfully recognising the importance of controller ergonomics.

Table 12 presents the aggregate scores for the testing of the ergonomics of each controller. It cements the same trend observed in the previous criteria; successive generations of controllers possess improved ergonomics.

Improvements and Conclusion

The initial hypothesis was that the ergonomics of video game controllers would improve over time due to manufacturers recognising its importance. While there is certainly considerable evidence to suggest that this hypothesis holds true, a troubling issue is that all four of the controllers failed the test for the diameter of the face buttons, which are a vital part of controllers bar the analogue sticks.

It was thought that this might be a deliberate decision on the manufacturers' parts to optimise their controllers' usability when playing games. To test whether this was truly the case, a prototype for an ideal controller that perfectly met every criterion was manufactured and tested. It was 3D modelled in accordance with every ideal anthropometric dimension used to test the four controllers in this study. Figure 24 depicts the process of 3D printing the prototype controller to produce a 1:1 scale model of the proposed controller.

According to the initial assumptions, this prototype controller would be perfect due to its adherence to the ideal anthropometric values. To validate this assumption, the controller was tested by collecting user feedback from the same users that provided feedback for criterion 5 in the previous sections. Figure 25 shows the 3D model of the prototype and a user testing the 3D printed model.

The full user feedback for the prototype is given in the appendix. The predominant complaint amongst all the users was that the prototype's face buttons seemed too awkward to use effectively. This comment came as a surprise as the controller followed every ideal anthropometric value and was supposedly ergonomically perfect. It was later realised that by maintaining the distance between the face buttons, the centres of the buttons were placed further apart, forcing users to cover a larger area when switching between the face buttons. Perhaps it is because of this reason that controller manufacturers chose to design smaller face buttons.

Controller Specification Aspect	PS4	Xbox 360	Original Xbox	SEGA Genesis
Face Button Diameter	0	0	0	0
D-Pad Diameter	0	1	1	0
Analogue Stick Diameter	1	1	1	0
Trigger Width	0	1	1	0
Face Button Distance	1	0	0	0
Analogue Stick Movement Angle	1	1	1	0
Face Button Force	1	1	1	1
D-Pad Force	1	1	1	1
Analogue Stick Force	1	1	1	0
Affordance Score	18	15	11	7
Total Score	24	22	18	9

Table 12: Overall controller Ergonomic scores.

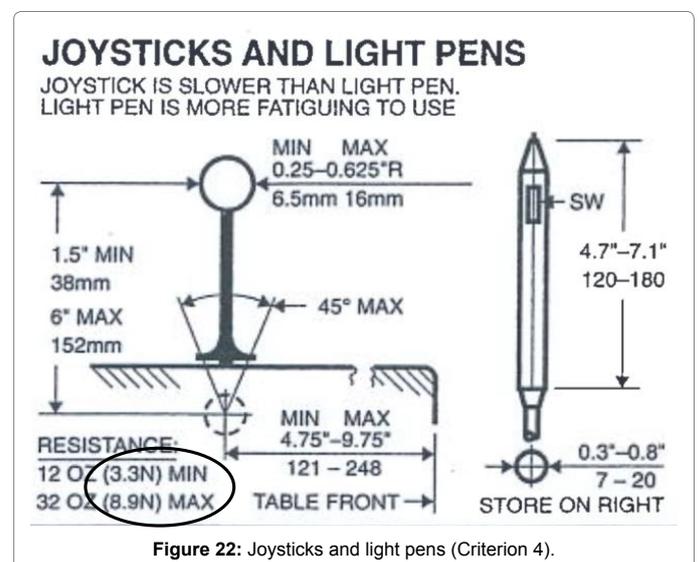
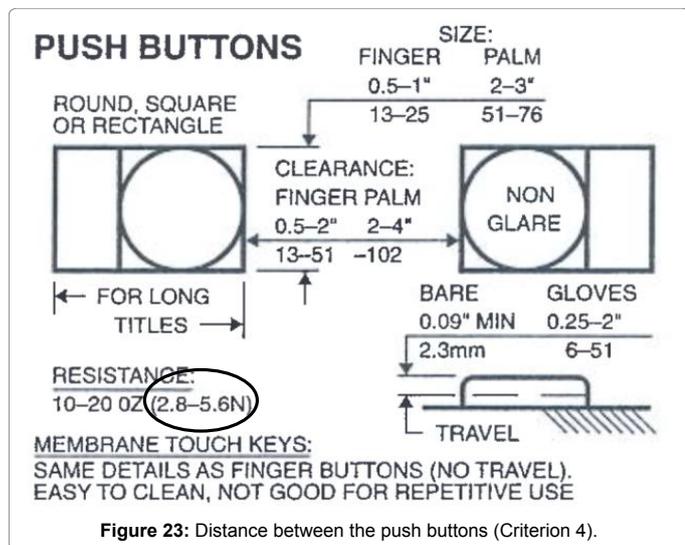


Figure 22: Joysticks and light pens (Criterion 4).



The hypothesis stated at the beginning of the study, that video game controllers have experienced considerable ergonomic development over time to fit the anthropometrics of a variety of users, can certainly be said to hold true. However, the failure of all four controllers' face buttons to meet the required minimum diameter raises doubts whether manufacturers truly designed their controllers in accordance with standard anthropometric values.

This shortcoming can be addressed by concluding that video game controllers are specialised devices made to fulfil the sole purpose of gaming, and so they cannot be effectively used as input devices for other purposes as of yet. They have features that cannot be identically adapted from other handheld devices, and so not all the standard anthropometric values used for the design of these devices can be applied to video game controllers. Regardless, video game controllers have undoubtedly experienced immense ergonomic development in their design over the years to become devices that are effective and satisfying in their usage. Perhaps these controllers will one day set their own distinct anthropometric standard that will be used to improve other everyday handheld devices.

References

1. Entertainment Software Association (2014) Annual Report.
2. Diemicke R (2006) 10 Worst 1st Party Controllers of All Time-Terrible Controllers 10 through 7.
3. <http://andrewd.ces.clemson.edu/courses/cpsc414/spring14/papers/group2.pdf>
4. Brown MA MacKenzie IS (2013) Evaluating Video Game Controller Usability as Related to User Hand Size. MHCI 114.1-114.8.
5. <http://www.ign.com/lists/top-25-consoles/5>
6. Calvert J (2003) Controller S becomes Euro Xbox Standard.
7. Tilley AR (1993) The Measure of Man and Woman. New York: Whitney Library of Design.

