Beyond the Gamepad: HCI and Game Controller Design and Evaluation

Chapter · December 2010

DOI: 10.1007/978-1-84882-963-3_12

4 authors:

Michael Anthony Brown
University of Nottingham

Aidan Kehoe
Logitech

Jurek Kirakowski
User Experience Solutions

Ian Pitt
University College Cork

Beyond the Gamepad: HCI and Game Controller Design and Evaluation

Abstract

A game controller, and how that controller is supported in a game, can have a significant impact on a player's gaming experience. In recent years there has been an increasing amount of computer game focused HCI research, but the impact of controller-related issues on user experience remains relatively unexplored. In this chapter we highlight the limitations of current practices with respect to designing support for both standard and innovative controllers in games. We proceed to explore the use of the McNamara and Kirakowski's (2006) theoretical framework of interaction in order to better design and evaluate controller usage in games. Finally, we will present the findings of a case study applying this model to the evaluation and comparison of three different game control techniques: gamepad, keyboard and force feedback steering wheel. This study highlights not only the need for greater understanding of user experience with game controllers, but also the need for parallel research of both functionality and usability in order to understand the interaction as a whole.

1 Introduction

Over its brief history, human-computer interaction (HCI) has developed a multitude of techniques for measuring and evaluating user experience with technology (Kirakowski & Corbet, 1993; Nielsen, 1993; Rubin, 1994; ISO, 1998a; Brown, 2008). Many of the design considerations and usability issues that arise in game software are significantly different from those encountered in other software genres. For example, a game that allows a player to complete quests quickly and easily might score highly with respect to ISO 9241-11 (1998b) software efficiency and effectiveness measures ; but it would probably rate very low with respect to user satisfaction because of the lack of challenge. As a result, in recent years we have seen the emergence of HCI research focused on computer games, addressing the unique challenges that this area presents (Desurvivre et al., 2004; Federoff, 2002; Jørgensen, 2004; Kavakli & Thone, 2002).

The visual and audio presentation capabilities of gaming platforms have increased dramatically over the last twenty years, and much of the associated research has focused on these aspects of games. However, the game controller, and how that controller is supported in the game, can have a significant impact on the player's gaming experience. It is important that players should feel a sense of control over the game interface and the associated game controls. Mastery of the control system is an important part of most games (Johnson & Wiles, 2003).

Traditionally games have been designed to operate with standardized (or de facto standardized) platform-specific controllers, e.g., each game console has an associated standardized first-party controller design. It has been recognized that controls are one of the most difficult areas in which to innovate within a game (Rabin, 2005). Most games take a conservative approach and adhere to the recommended controller guidelines for their target platforms. Also, for many game genres, there are existing control schemes that are accepted as norms.

Recently, an increasing number of games have added support for new and innovative controllers in their games (Kane, 2005; Marshall, 2006). Incorporating support for new controllers in games offers opportunities to enhance the gaming experience by enabling interaction styles that are not possible using standard controllers, e.g., guitar controller with the Guitar Hero game, microphone used in Karaoke Revolution, force feedback steering wheel in Gran Turismo, etc. Support for controllers must be carefully planned and designed, and their performance evaluated. While some work has been conducted regarding the development of input devices (Cummings, 2007; Hoysniemi, 2006) and how they affect user performance (Kavakli & Thone, 2002; Klochek & Kenzie, 2006), the effects of game controllers on user experience is yet to be explored in detail.

In this chapter we describe how McNamara and Kirakowski's (2006) theoretical framework for understanding interactions with technology can be applied to the evaluation of controllers in games. Using this model as a guide, a user study was performed to explore the use of a range of game controllers in terms of functionality, usability and user experience. The framework is described in section three, below. The results of this study are presented and discussed in section four.

2 The Evolution of Game Controllers

As far back as the 1950s, general purpose computing platforms have been used for the development and playing of computer games. The pre-existing input and output capabilities of the computing platforms were leveraged for game play purposes. For example, in 1961, the initial implementations of the "Spacewar!" game, running on the DEC PDP-1, used the test-word toggle switches for player input (Graetz, 1981).

However, even in those early game environments the opportunities for specialized game controllers were recognized. The location of the toggle switches on the

DEC PDP-1 (c. 1960), relative to the visual display, gave one of the players the advantage of being able to see the display more easily. To overcome this problem a dedicated control box incorporating these switches was constructed. In addition to implementing the required switch functionality, the control box configuration also utilized more natural and intuitive mappings for the controls, e.g., the rotation switch was configured so that moving the switch to the right resulted in the craft being rotated to the right; a lever-style control could be moved to accelerate the craft. Graetz, one of the “Spacewar!” developers, stated that the new control mechanism “improved ones playing skills considerably, making the game even more fun” (Graetz, 1981).

Over the past decades, the improvements in processor speeds and storage have been matched by developments in the field of input and output devices. During this time, the evolution of game software and game controllers has been inextricably linked. Games have influenced the design of game controllers, and game controllers have influenced the design of games (Cummings, 2007). Many games, especially those played on general purpose computing platforms, have been designed to use the pre-existing control methods for the platform. However, the development of new generations of dedicated gaming platforms, and sometimes specific games, has often incorporated innovation in the area of game controllers.

2.1 Standard Game Controllers

The majority of games have been designed to operate with standardized (or de facto standardized) platform-specific controllers, e.g., each game console has an associated standardized first-party controller. Today most games running on consoles support the standard console controller; most games running on personal computers support input via the keyboard and mouse; PDA games are played with a stylus; mobile phone games are played using the standard phone controls; and the recent proliferation of devices incorporating a touch screen have also supported that interaction method in games. Thus, the majority of games are designed to incorporate support for existing control methods.

Much of the innovation in the area of game controllers has been associated with dedicated gaming platforms. There are a number of popular-press books that document the development of the console games industry and technology (Sheff, 1993; Kent, 2001; Forster, 2005). Throughout this almost 40-year development of game consoles, newer generations of consoles were typically accompanied by some degree of development and innovation in the associated game controller. In many cases the level of controller innovation for a new console was relatively minor, and in some cases there was significant change and innovation, e.g., Nintendo Wii Remote, Nintendo Entertainment System gamepad, etc.

Controllers for dedicated gaming platforms have traditionally been very tightly integrated with the console system electronics, supporting firmware/software and games. Through the 1970s and early 1980s, players used a variety of controls (switches, dials, sliders) that were an integral part of the console itself, e.g., Magnavox Odyssey 100-500 series, Coleco Telstar series, etc. From the early 1980s onwards it became increasingly common for the controllers to be distinct separate physical entities (usually gamepads or joysticks) that were connected to the game console through a cable, or in more recent systems, a wireless link.

Each of today's game consoles has a "standard" controller that was designed with the capabilities of its console in mind, and is tightly coupled to that system. These standard controllers are explicitly supported by the console platform libraries and SDKs that are used by game developers. Part of the QA and approval process for a console game typically includes verification of appropriate controller support, i.e., ensuring that the game implements the controller support in accordance with the console usage guidelines.

A "standard" controller, with support implemented in games in a uniform manner, can help ensure a consistent interface for the user while playing games on that platform. Most games take a conservative approach and adhere to the recommended controller guidelines for their target platforms. Also, for many game genres, there are existing control schemes that are accepted as norms. It has been recognized that controls are one of the most difficult areas in which to innovate within a game (Rabin, 2005).

2.2 Focus on Innovative Game Controllers

While uniformity of game controller support can be beneficial, it can also be very limiting for both the game designer and the player (Rabin, 2005). Even in the early years of game console systems, when the console and game controls were part of the same mechanical enclosure, there were attempts to make controllers that were targeted towards a particular game or genre of game, e.g., Atari Stunt Cycle (Atari Inc., 1977) and steering wheel controller. These types of development mirror what was also happening in the arcade machine arena, i.e., the use of dedicated controllers for flying games, racing games, etc.

In recent years an increasing number of games have added support for new and innovative controllers in their games. Incorporating support for innovative controllers in games offers opportunities for a game to distinguish itself in the market place (Kane, 2005; Marshall et al, 2006). Custom controllers, designed to operate with specific games, offer possibilities to enhance the user experience in games by enabling interaction styles that are not possible using standard controllers, as described above.

While designing and implementing a custom controller offers opportunities to greatly enhance a game, it also introduces significant additional work, more project schedule risk, and probably an increased retail price for the game-plus-controller bundle. However, apart from platform-specific checklists, the advice available to guide designers and developers considering new or innovative controllers is very limited. Support for innovative controllers must be carefully planned and designed, and their performance evaluated. Problems associated with developing and implementing support for custom controllers is frequently listed in the post-mortem reports which are published on a monthly basis in Game Developer magazine (Game Developer Magazine, 2008).

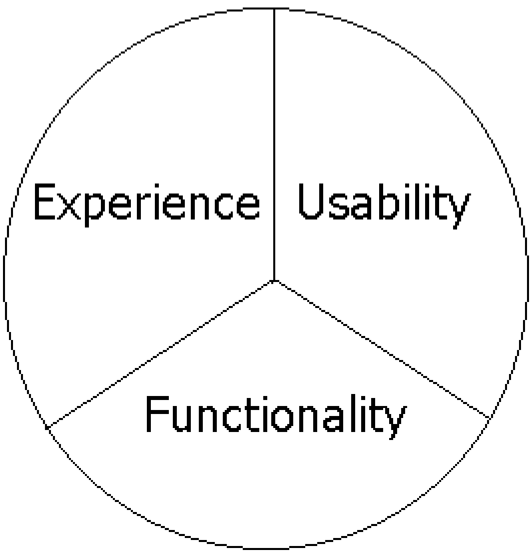
3 Evaluating Game Controllers (Experience, Usability and Functionality)

As with all technology, the interaction between humans and game controllers is multifaceted and complex. This section describes McNamara and Kirakowski's (2006) theoretical framework for understanding interactions with technology and discusses the implications of applying this model to game controllers.

3.1 Introduction to the Facets of Game Experience

Recent developments in human-computer interaction have highlighted the importance of allowing for user experience in the design of technology. This need for high quality user experience is especially important for computer games, as their primary function is to entertain. This revelation has lead to some theoretical difficulties, as the concept of user experience does not easily fit into the traditional HCI fields of usability and ergonomics. In order to fully understand interactions with technology, we must understand the various aspects of the interactions and how these aspect impact on each other.

Figure 1. Areas of Technology Usage



(from McNamara & Kirakowski, 2006)

McNamara and Kirakowski (2006) propose a three factor model for understanding the interactions between humans and technology, represented in Figure 1. This theoretical framework presents three separate but co-dependent aspects of human computer interaction. 'Functionality' describes the technology side of the interaction, focusing on the technological possibilities of the interaction. Conversely, 'experience' describes the purely human side of the interaction. This factor looks at how the interaction impacts on the person involved by asking questions such as: do they enjoy the interaction? does it make them happy? etc. Finally, 'usability' looks at the dynamics of the interaction itself, is it efficient, effective and satisfying? They propose that in order to fully understand an interaction we must study each of these three factors.

This section of the chapter looks at each of these areas in detail and discusses the implications of applying this framework to the evaluation and design of computer game controllers.

3.2 Functionality and Game Controllers

This aspect describes the purely technology-based part of the interaction. Key questions in this area are: 'does it work?' and 'what does it do?'. This is the one aspect of the interaction that is relatively independent of both environment and user. Functionality can be measured by comparison of the quantity and range of outputs produced by each controller with the possible inputs recognised by the game.

Looking at game controllers, it becomes clear that the primary function is to facilitate user interaction with computer game software. Traditionally controllers only supported a one-way interaction from the user to the game, with audio visual devices providing feedback from the game to the user. However, the recent development of in-controller feedback means that the interaction with game controllers is now bi-directional. This means that, when considering game controller functionality, we must consider the range of input and feedback that a given control method can provide.

Another important issue of game controller functionality is the level of support for the controller in a given game. A controller with a wide range of possible inputs and outputs is of little benefit if game software does not support it. Assessing controller functionality in isolation from software is fairly straightforward, as the range and sensitivity of various inputs and outputs can be easily tested. However relating this to in-game functionality is a more complex issue, as the range and sensitivity of a controller may not be supported or necessary for a given game.

3.3 Usability and Game Controllers

Usability is the traditional focus of HCI research and describes the interaction between people and technology. A classic description of usability is *"The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" (ISO, 1998). This definition highlights four core concepts central to interaction: effectiveness, efficiency, satisfaction and context of use. Each of these concepts is important when discussing game controller design.

Effectiveness describes the ability of the user to complete specific tasks with the technology. This goes further than basic functionality, as not only must the technology have the potential to perform tasks, the user must also be able to operate the technology sufficiently to actually complete these tasks. The importance of effectiveness in game controller design is obvious: if users can not use a controller to perform game tasks, they will be unable to interact with the game in any meaningful way.

The importance of efficiency in game controller design is a more complex issue. Efficiency considers the resources that must be expended by the user to complete tasks. These resources can be mental effort, physical effort or time. In terms of computer games this is closely linked to concept of difficulty: i.e. if a game requires a large amount of resources (time, skill, mental effort etc.), then it is described as difficult and, conversely, if it requires few resources it is described as easy. This might seem to be of limited importance when discussing game controllers, as the main focus of games is to enjoy playing them, not to effectively complete tasks. However, as Csikszentmihalyi (1975) reports, completing tasks that are easy can become boring and tasks that are difficult can become frustrating. This need for balance of effectiveness presents a dilemma in game controller design. Do you design a controller that is as efficient as possible and rely on game designers to introduce sufficiency difficulty to ensure the interaction does not become boring? Or design a control method that incorporates challenges of its own, no matter what game it is used with?

The concept of satisfaction deals with how the interaction impacts the user; are they free from discomfort and do they have a positive attitude towards the interactions? Once again the importance of this concept to game controller design is fairly obvious, as playing computer games is an entertainment-driven activity, and the interaction should be satisfying. Unlike efficiency, effectiveness and context of use, satisfaction is purely subjective. While the other core concepts of usability can to some degree be directly observed, satisfaction must be assessed solely on the basis of user feedback. This can cause problems in game controller design, as variables such as context of use can influence user report and distort findings.

Context of use is unlike the other concepts discussed as it is not a vital part of usability, but is a factor that must be considered when studying efficiency, effectiveness and satisfaction. Basically, context of use describes the situation in which an interaction is happening (Bevan and MacLeod, 1993) . It is important to consider that this refers not only to the physical environment, but also to individual differences and the social environment in which the interaction is taking place. While this concept is vital when studying all forms of technology, it is especially important when working with control devices because, as interaction facilitation devices, they introduce additional complexity that must be considered. The device a controller is being used to control has a huge influence on the usability of the interaction. In terms of game controllers, this means both the hardware (PC or console) and software (the specific game) must be considered in design.

3.4 Experience and Game Controllers

This final aspect of interaction design is perhaps the most recent to be explored. Experience refers to the psychological and social impact technology has on users. While this is related to the usability concept of satisfaction, it has a much wider scope, looking at interaction in a much broader sense than merely task completion. When studying experience, concepts external to the interaction must be considered, for example aesthetics, marketing, social impact, attachment and mood can all affect users' experience of interacting with technology.

Once again, the nature of game controllers as intermediary devices can make studying this aspect of user interaction difficult. In addition to the social, psychological and environment factors that must be considered when looking at experience of any technology, the hardware and software that is being controlled may also impact on user experience with game controllers. Little research or theory exists relating to user experience with game controllers, making it impossible to predict what factors are key to users experiences in this area. However, the tools needed to explore this area do already exist; qualitative psychological methods such as critical incidents technique, semi-structured interview, grounded theory, content analysis and ethnography have been use to evaluate experience in a wide range of fields (McCarthy and Wright, 2004) and their flexible nature means they can be easily applied to the study of game controllers.

3.5 Evaluation and Design of Game controllers

This section discusses the impact of this framework on research and design in this field. First, current literature in this area is explored, and then the implications for design are discussed.

Looking at recent research into controllers in general, it is found that a significant number of research papers have explored the performance of pointing devices (including mice, touch-pads and trackballs), keyboards in traditional desktop/laptop computing scenarios, and keypads usage on handheld devices (Card et al., 1978; MacKenzie, 1992; Silfverberg et al, 2000). In recent years, HCI researchers have also explored a variety of increasingly popular interaction methods including gesture, touch, haptics and styluses (Dennerlein et al., 2000; Forlines et al., 2007, Albinsson et. al, 2003). Most of this work has been concerned with the effectiveness and efficiency of the input methods, but user satisfaction has also been considered (Brewster et al., 2007; ISO, 1998b).

Despite the fact that game control has been highlighted by many studies as an important aspect of game design (Federoff, 2002; Desurvivre et al, 2004; Adams, 2005; Hoysniemi, 2006; Pinelle et al, 2006; Johnson, 2008; Falstein and Barwood, 2008) little research has been conducted that focuses on game controllers. Some work has studied the development of input devices and how they affect user performance (Kavakli and Thone, 2002; Pagulayan, 2003; Klochek, 2006), however the effects of game controllers on user experience has yet to be explored in detail. According to McNamara and Kirakowski’s (2006) model, we will not be able to fully understand the interaction involved with game controllers until it has been studied in terms of functionality, usability and user experience.

Current game controller design practice continues this pattern, with an emphasis on the functionality aspects but little attention pained to usability, still less to user experience. For example: the game-play and console compliance checking activities incorporate evaluation of controller support. The associated checklists typically contain very specific advice with respect to assignment of functionality to buttons. Apart from this very platform-specific advice, the guidelines and heuristics related to support of standard controllers is very limited.

The next question that must be answered is how adopting this model impacts game controller design? The main impact of this model is in the evaluation stages of controller design. Currently, little research exists to help focus game controller evaluation on the aspects of game controllers that have the greatest effect on user interaction. This lack of focus leaves controller designers with two choices when it comes to evaluation: either perform a huge range of evaluation to ensure that all aspects of the controller are examined, or perform a few tests and hope that most of the important issues are found. Neither of these are ideal solutions as the first is costly to perform and it may be even more costly to correct all the issues found, and the second is likely to miss key issues and produce a poor product. The McNamara and Kirakowski (2006) model highlights the distinct aspects of the interaction, allowing designers to perform fewer evaluations but still investigate each of the important aspects of the interaction. Ensuring that controller functionality, usability and user experience are all evaluated means that all the vital aspects of the controller can be assessed without performing a huge range of evaluations.

4. Case Study

In order to further explore this area, a case study was designed to evaluate both standard and innovative computer game controllers usages in a game. This study focused on control of racing games and evaluated keyboard and mouse, standard gamepad and force feedback steering wheel control methods with respect to each aspect of user interaction, as described by McNamara and Kirakowski (2006).

4.1 Justification

In order to fully explore the interaction between user and game controller, each controller was assessed in terms of functionality, usability and user experience.

• Functionality: This describes the purely technology based part of the interaction. Key questions in this area are: 'does it work?' and 'what does it do?'. This is the one aspect of the interaction that is relatively independent of both environment and user. Functionality was measured by comparison of the quantity and range of outputs produced by each controller with the possible inputs recognised by the game.

• Usability: This is the traditional focus of HCI research and describes the Efficiency, Effectiveness and Satisfaction of the interaction. This quality is dependent not only on the user, but also the environment in which the interaction takes place. Each aspect of usability was measured independently. Efficiency was measured in terms of mental effort required to use the controllers: the lower the mental effort required, the more efficient the interaction with the controller. Mental effort was measured using the self-report Subjective Mental Effort Questionnaire (Arnold, 1999). Effectiveness was measured via lap time. The faster users can complete a lap using a controller, the more effective the interaction, as fast lap completion is the primary task in racing games. Satisfaction was measured via the Consumer Product Questionnaire (CPQ) (McNamara, 2006), a standardized measure for evaluating user satisfaction with electronic consumer products.

• Experience: The final aspect describes the users' experiences of the interaction. As this aspect is purely subjective in nature, it can be difficult to measure and is dependant on a huge range of psychological and social factors external to the interaction itself (including aesthetics, advertising and social desirability) (McCarthy and Wright, 2004). This was measured in two ways. Firstly, users were asked to report their preference between each of the controllers. Critical Incidents Technique (CIT) (Flanagan, 1954) was used to collect qualitative data describing user experience.

4.2 Methodology

The aim of this study was to investigate the differences between keyboard, gamepad and steering wheel as control methods for playing a racing game, in terms of functionality, usability and user experience.

A total of twelve subjects took part in this study. Gender balance was reasonably equal with five female and seven male subjects. The mean age of the participants was 24.6, with ages ranging from 19 to 30. Participants were also asked if they drive regularly as this may give them an advantage with the steering wheel controller, five responded that they did. They were also asked if they had any experience of racing games, all except subject 1 responded that they had little of none.

The test system was a HP Compaq dc7800p running Windows XP. The following three controllers were evaluated in the study:

Keyboard: Dell USB keyboard

Gamepad: The Logitech Dual Action is a USB gamepad, with two mini-joysticks (similar to those commonly used on game consoles) and 12 digital buttons.

Steering Wheel: The Logitech MOMO Racing is a USB force feedback device, with an analog steering wheel, analog accelerator and brake pedals, and 10 digital buttons.

This combination of devices allowed exploration of the use of digital-only controls (on the keyboard), mixed analog-plus-digital controls (on the gamepad) and analog-only controls, as shown in Table 1. Custom logging software was developed to record all the reports generated by the controllers during game play.

Control	**Keyboard**	**Gamepad**	**Steering Wheel**
Steer	left/right arrow (D)	left mini-stick (A)	wheel (A)
Accelerate	up arrow (D)	button 1 (D)	pedal (A)

Brake	down arrow (D)	button 0 (D)	pedal (A)

Table 1. Game Controls for Each Device (A=analog, D=digital).

A single game was used in the study, Colin McRae Rally DiRT (Codemasters, 2007). In order to minimize the impact of game specific artifacts on the evaluation, a number of the game settings were fixed. The same difficulty level (amateur), control assignment, view (behind the car), car (Subaru Impreza) and track (Avelsbachring) was used for all subjects.

This study used a repeated measures type design with each subject taking part in every condition. The independent variable was the type of control method used and was operationalised in three conditions: Gamepad, Keyboard and Force Feedback Steering wheel. Each of the three aspects of technology interaction defined by McNamara and Kirakowski (2006) were measured as the dependant variables. These were operationalised with a variety of measures. Functionality was explored by comparing how the various game controllers supported the available game commands. Usability was measured in terms of the three vital components of usability as defined by the ISO (1998b). Efficiency was measured in terms of mental effort, as reported by completion of a Subjective Mental Effort Questionnaire (SMEQ). Lap completion time was used in order to measure effectiveness. Satisfaction was measured using the Consumer Products Questionnaire (CPQ). Finally user experience was measured via user preference reported on a five point scale and Critical Incident Technique.

In order to reduce confounding variables between conditions, a number of controls were used. The order of conditions was counterbalanced in order to counteract any effects due to learning. Each condition used the same software and hardware, except for the control method, so reducing the effect these may have on the evaluation. Participants also all used the same settings within the game such as view, automatic gearbox, and allocation of controls, as these factors may confound measures of efficiency and effectiveness.

4.3 Results

4.3.1 Functionality

Functionality describes the purely technology-based part of the interaction. The key issue to be considered is whether the controller supports the required functionality to enable the user to play the game. This is the one aspect of the interaction that is relatively independent of both environment and user. There are two issues to be considered. Firstly, are all the game commands supported by the controller? And secondly, the issue of exactly how the control is supported can also be important.

In some cases, controllers may not have the required number of controls to allow the player to invoke all the game commands. For example, flight simulator games typically support a larger number of game commands (often more than 30) than there are physical controls on a low-end joystick. In this case the player must select a subset of the game commands to be assigned to their joystick controls, and the remaining commands can be invoked via the keyboard (or perhaps not used at all by the player).

In the context of this study the DiRT game has only a small set of commands. In addition to steer, accelerate and brake, a small number of extra commands are also supported (change camera, handbrake, look left/right /back, gear up/down). Even though the use of all the game commands was not examined in the study, the various controllers had sufficient controls for all of these game commands to be assigned, i.e., 100% of the game commands can be assigned to the controllers.

In addition to considering whether specific functionality is supported, it is also important to consider how that support is implemented. The DiRT game supports both analog and digital inputs for the steer, accelerate and brake commands. Digital inputs are activated by via a key on a keyboard, or a button on a game controller. The game processes these inputs, and increases or decreases an analog value in response to the duration of the digital input being “on”. For example, turning on the digital input for the accelerate command results in an increase in vehicle speed that is a function of the duration of the “on” state (constrained, of course, by the game physics engine).

As shown in Table 2, the implementation of analog controls can vary across different game controllers. The steering wheel used in the study has 240 degrees of rotation reporting 1024 counts when the “raw” data reported to DirectX is examined. This results in the control’s angular resolution being 4.3 (1024 / 240) counts per degree of rotation. In contrast, the gamepad reports 255 counts, and can move approximately 25 degrees of rotation, which results in 10.2 counts per degree of movement. In fact this number for the gamepad is a high-side estimate, since gamepads have ‘deadzone’ around their centre area in which no movement is reported.

Control Parameter	**Gamepad**	**Wheel**
Physical Range (approx.)	25	240
Analog Counts	255	1024
Deadzone	Yes (center)	No
Angular Resolution (approx.)	Less than 10.2	4.3

Table 2. Gamepad and Wheel Controls

Thus while both the gamepad and steering wheel support analog steering, their response characteristics are very different, with the wheel being several times more precise in terms of angular resolution. This data show that in terms of functionality in the context of this game, the steering wheel is the superior control method, with the widest range of motion and sensitivity. Conversely, the keyboard has the poorest functionality, only accommodating binary input for both steering and acceleration.

4.3.2 Usability

The usability of each game controller was measured in terms of effectiveness, efficiency and user satisfaction.

	Completion Time	SMEQ score	CPQ score
Steering Wheel	04:39	72.92	20.83%
Gamepad	02:59	34.42	15.08%
Keyboard	03:13	42.58	6.25%

Table 3: Means scores on usability measures

Table 3 shows the results for each component of the usability analysis of the three controllers. In indicates poorer performance for the steering wheel compared to the other two control methods in terms of both completion time and SMEQ (low values of SMEQ indicate mental effort required). Gamepad and Key Board results for these two measures appear to be much closer. In terms of CPQ results, the Keyboard reports an extremely low result for satisfaction, with the Gamepad and Steering Wheel performing slightly better (50% on the CPQ is an average device score, according to the CPQ database). A series of one way repeated measures ANOVAs were used to determine the statistical significance of these results. ANOVA was used as it is a robust method of difference testing and performing multiple t-tests would increase the likelihood of a type II error. As an exploratory study an alpha level of 0.05 was used.

	Completion Time	SMEQ score	CPQ score
F Value	5.876	7.258	3.268
Degrees of Freedom	10	10	10
P	0.021	0.011	0.081

Table 4: ANOVA results for usability measures

Table 4 shows that the ANOVA results indicate significant results at an alpha level of 0.05 for completion time and SMEQ scores. Results for CPQ scores show the data approaches significance, but fails to reject the null hypothesis at a 0.05 alpha level. In order to further investigate the differences a post hoc STEP analysis was performed on each of the significant ANOVA results.

Completion time STEP results	Steering Wheel	Gamepad	Keyboard
Steering Wheel	-	0.014	0.027
Gamepad	-	-	0.4
Keyboard	-	-	-

Table 5 – P values for STEP analysis of completion time ANOVA results

Table 5 shows the probability values for the STEP analysis of the completion time data and reveals significant differences between Gamepad and Wheel, and Keyboard and Wheel. This shows that the steering wheel performed significantly worse than the other two methods in terms of effectiveness.

SMEQ STEP results	Steering Wheel	Gamepad	Keyboard
Steering Wheel	-	0.014	0.027
Gamepad	-	-	0.4
Keyboard	-	-	-

Table 6 – P values for STEP analysis of SMEQ ANOVA results

Table 6 reveals similar results for the STEP analysis of the SMEQ data. Significances were found between Steering wheel and Gamepad, and between steering wheel and keyboard. This shows that the steering wheel also performed significantly worse than the other control methods in terms of efficiency.

In summary, the usability data collected shows an interesting trend in terms of the steering wheel. This controller scored significantly worse than both of the other control methods in terms of efficiency and effectiveness (as measured by Completion Time and SMEQ), but scored the highest in the measure of user satisfaction. This set of results suggests that while the steering wheel was not an effective or efficient controller, the participants enjoyed using it. Keyboard data shows the opposite trend, with good efficiency and effectiveness scores, but the poorest satisfaction results. Finally the Gamepad performed the best of three controllers in terms of usability, producing the best lap times, the lowest CPQ scores and a reasonable score in the CPQ, compared to the other controllers. It is also worth noting that all three control systems performed poorly in terms of user satisfaction, with means scores ranging from 6.25 to 20.83%. The lack of statistical significance may be due to a 'floor' effect: i.e. the CPQ scores could hardly get much worse.

4.3.3 User Experience

The data collected to measure user experience took two forms, firstly user preference was gauged, and secondly CIT was used to report user attitudes to the devices.

User Preference	Keyboard – Gamepad	Keyboard – Steering Wheel	Steering Wheel - Gamepad
Mean	4	2.5	3.92
Std Dev.	1.28	1.57	1.44

Table 7 – User preference Scores on a 1-5 scale

Table 7 presents the mean user preference scores and shows a preference towards the gamepad compared to the other two controllers, and a preference for the keyboard over the steering wheel. In order to test the significance of these results, one-way repeated measures ANOVA was performed at alpha level 0.05, producing an F value of 3.015 with 10 degrees of freedom. This falls outside the critical region and so does not show statistical significance.

As the CIT produces quantitative data, a more detailed analysis is required. The responses for each game controller were formed into categories using Content Analysis.

Steering Wheel/ Category	Positive Comments	Negative Comments	Total
Sensitivity	3	9	12
Feedback	7	4	11
Easy to pick up	7	4	11
Realism	9	2	11
Physical Characteristics	4	3	7
Learning Potential	1	3	4
Miscellaneous	0	1	1
Total	31	26	57

Table 8 – Content analysis of steering wheel comments

Table 8 shows the results of the content analysis of the steering wheel comments. This table highlights *sensitivity*, *feedback*, *easy to pick up* and *realism* as the most reported aspects of users experience with this device.

The *Sensitivity* comments highlight the high sensitivity of left/right steering using the wheel. For example:

“. . . impressive accuracy while playing.” (Subject 1, positive)

“Controller is very sensitive to movement, it takes a while to judge accurately how much force is required.” (Subject 7, negative)

“Hard to control. The steering was highly sensitive.” (Subject 11, negative)

While the majority of these comments are negative, showing frustration at the highly sensitive controls, three of the subjects listed this as a positive feature that actually enhanced their game play experience.

Comments in the *Feedback* category discuss the force feedback produced when using the steering wheel. For example:

“The motion of the wheel when on rough terrain (vibration) added to the experience of crashing.” (Subject 6, positive)

“The vibrations of the wheel were a nice effect in making it seem like you were really on the terrain, like the grass.” (Subject 12, positive)

“The motion/vibration of the wheel often made turning the wheel very difficult - it moved a lot less smoothly” (Subject 6, negative).

Again the comments in this category are both positive and negative. The positive comments show an appreciation of the fun and realism that force feedbacks adds to the interaction, while the negative comments mention situations where it got in the way of playing the game. This shows the care with which innovative controller features should be applied so they add to the game experience without getting in the way of the basic features of the game, in this example steering.

The *Easy to pick up* comments mention instances where this control system was or wasn’t easy to pick up and use. Some found the familiar steering wheel and pedals provided an intuitive control system, but for others the reproduction of driving conditions was not accurate enough to make it easy to pick up. For example:

“Using a steering wheel is quite intuitive; it's obvious how it works.” (Subject 6, positive)

“The accelerator and break peddles were awkward to use at first and I never really got comfortable with them.” (Subject 3, negative)

The *Realism* category produced the most positive comments for the steering wheel, with only two negative comments from eleven. These comments mainly praise the realism of this control method and two of the comments call for even more realism. For example:

“The wheel combined with the pedals made it seem like a very realistic driving system.” (Subject 6, positive)

“Steering wheel only had half turn each way rather than the 1.5 as I am used to when driving.” (Subject 8, negative)

Keyboard/ Category	Positive Comments	Negative Comments	To-tal
Ease of use	10	3	13
Sensitivity	3	8	11
Physical characteristics	5	6	11
Realism	0	3	3
Comfort	0	2	2
Feedback	0	2	2
Familiarity	2	0	2
Total	20	24	44

Table 9 – Content analysis of keyboard comments

Table 9 shows the results of the content analysis of the keyboard comments. It is worth noting that this is the only control method that received more negative comments than positive ones. The categories that contain the most comments and are the focus of the evaluation are *Ease of Use*, *Sensitivity* and *Physical Characteristics*.

The *Ease of Use* category contains comments discussing how easy the keyboard was to use. Most of these are positive comments focusing on the simplicity of the interface, but some mention the limited control that is afforded by keyboard control. For example:

"The keys were very easy to understand. I had no problem understanding the directions and in using them during game play." (Subject 3, positive)
"Actions didn't translate well to game. Even though controls are simple, car was difficult to control and judge." (Subject 7, negative).

The category containing the most negative remarks was *Sensitivity*, and contained comments relating to the binary nature of the keyboard input. A few comments praised this as easy to use, while most of them criticised the lack of sensitivity. For example:

"Easier to make incremental adjustments during steering." (Subject 2, positive)
"Breaking was instantaneous, I had no control over slowing down, it was stop or nothing." (Subject 3, negative)
"Very difficult to control the strength of the control/action by simply pressing one key." (Subject 4, negative)

Comments in the *Physical Characteristics* category discuss the implication of the physical layout of the keyboard, either praising the localised controls or criticising it for being cramped. For example:

"Small choice space-i.e. arrow keys within easy range of fingers" (Subject 2, positive)
"Spacing of input keys is a small bit cramped." (Subject 9, Negative)

Gamepad/ Category	Positive Comments	Negative Comments	Total
Comfort	8	2	10
Learnable	4	3	7
Sensitivity	3	4	7
Personal Preference	2	5	7
Ease of use	6	1	7
Feedback	0	3	3
Realism	1	1	2
Misc	2	0	2
Total	26	19	45

Table 10 – Content analysis of gamepad comments

Table 10 shows the results of the content analysis of the gamepad comments and shows that the comments in this category are more evenly spread across the categories produced; this suggests that there were not any aspects of the interaction that were experienced by all the users. The categories that contain the most comments are *Comfort*, *Learnable*, *Sensitivity*, *Personal Preference* and *Ease of Use*.

Comfort is the largest category produced and contains the most positive comments. These comments simply talk about how comfortable the gamepad is. For example:

"Very comfortable. I could hold it all day long." (Subject 3, positive)
"Makes my thumb sore after playing for a while." (Subject 1, negative)

Comments in the *Learnable* category talk about how easy or difficult it is to get used to using the gamepad controller. For example:

"Very familiar. I knew exactly how it worked within very little time" (Subject 3, positive).
"Maybe if someone used this for the very first time it would be difficult to figure out" (Subject 7, negative).

It is interesting to note that while several users mention this method is easy to learn, none talk about how intuitive it is, as they did with both the steering wheel and the keyboard. This may suggest that it may be familiarity with this device rather than an intuitive interface that makes learning easier.

The **Sensitivity** comments highlight the positive and negative effects of steering, acceleration and break sensitivity. For example:

"Natural feeling, right sensitivity" (Subject 1, Positive)
"The acceleration and breaks didn't seem to work well together. It was hard to break slightly; you had to come to a complete stop." (Subject 11, negative)

Comments in the *Personal Preference* category discuss issues relating to control assignment setting in the game. Most of these comments are negative, perhaps representing the fact that the participants were not allowed to alter these settings during the study. For example:

"Would have preferred to accelerate on the 'trigger' buttons" (Subject 2, negative)
"The button for the break should be to the right side, not above the accelerator." (Subject 8, negative)

The *Ease of Use* category contains comments relating the simplicity (or lack of) using this control method. Most of these comments are positive with only a single comment stating that this device is difficult to use. For example:

"Very easy to use. Actions were displayed accurately in the game. It was easy to judge how much movement/force was required." (Subject 7, positive)
"The joystick seems sometimes a little bit difficult to use." (Subject 5, negative)

Overall, the user experience data has revealed several interesting trends. The most obvious of these is the mixture of positive and negative comments throughout the categories relating to all three control methods. The vast majority of categories discovered contain both positive and negative comments; this trend highlights the importance of individual differences when analyzing game controllers. What some users may see as a positive feature or aspect of a game controller, others may view in an extremely negative light. For example, when discussing the binary nature of the keyboard, one subject found it much easier to steer with, while another found the lack of sensitivity frustrating.

"Easier to make incremental adjustments during steering." (Subject 2, keyboard, positive)
"Very difficult to control the strength of the control/action by simply pressing one key." (Subject 4, keyboard, negative)

4.4 Conclusions

While each of the evaluations produced interesting results, a more complete picture can be gained by looking at a combination of all three measures. While a complete analysis of all the data collected falls outside the score of this chapter, this section with discuss the overall finding, then highlight a single issue that was reported by several of the analysis methods and explore it in more detail

The steering wheel is an attractive device which supports all the functions needed by the game commands, and therefore may be a selling point for the game. In the hands of an inexperienced user, however, it will lead to poor game performance. None the less, at least initially, users will feel satisfied with it.

Although the gamepad comes out above the steering wheel and the keyboard on usability performance measures, the keyboard has the advantage that it is regarded as massively easy to learn. "Experience" and "usability" in this case seem to be telling different stories. Which should the game designer go for if there is a choice to be made? If there is a payoff between the keyboard and the gamepad, the designer may well choose to not support the gamepad if user experience is the key issue.

The issue of controller sensitivity is one that seems to have an impact on all three aspects of the interaction. The user experience analysis highlighted controller sensitivity as an important aspect of experience for each of the control methods. Categories within each analysis highlighted each control method’s advantages and disadvantages in terms of sensitivity. The results suggest that this aspect of the interaction was the most influential when using the steering wheel, as nine comments mentioned sensitivity as a problem. However, in terms of functionality the steering wheel is clearly superior, being sensitive to small gradations in terms of steering, acceleration and breaking.

To examine this in more detail, an analysis of the data collected by the logging software for subject 1 (the subject with the best laps times using the wheel) and subject 5 (a subject with close to average lap times with the wheel) was conducted.

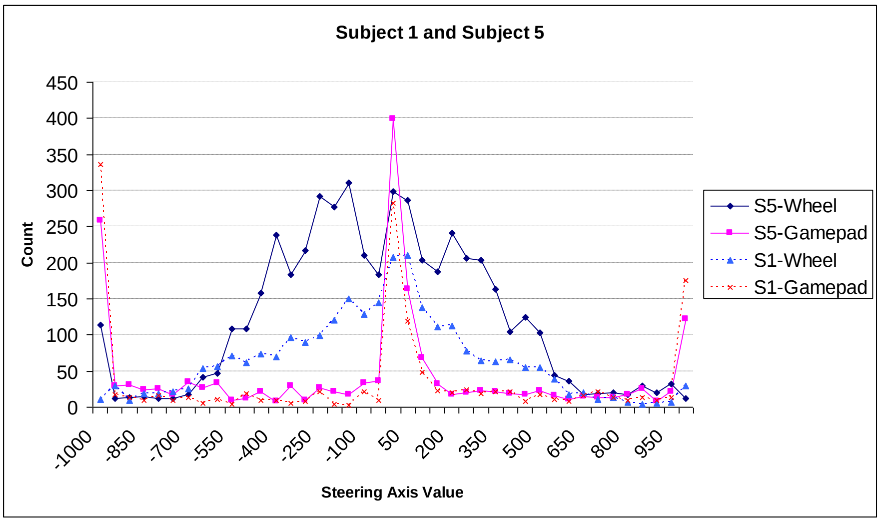


Figure 2. Device Steering Reports for Subjects 1 and 5.

Figure 2 shows the reports captured by the logging software for subjects 1 and 5, while using the gamepad and steering wheel to control the steering axis while driving the two timed laps of the track. The data from both controllers has been normalized; -1000 is the controller axis at the extreme left; +1000 is the controller axis at the extreme right; 0 is the center position for the controller.

The bias of data towards the left hand side of the chart is a result of the track being driven in an anti-clockwise direction. As can be seen in Figure 2, the profile of reports generated by both subject 1 and subject 5 while using the gamepad is very similar. The distribution of the data shows that little of the analog capability of the mini-joystick on the gamepad is being used. Most of the reports are either close to the axis centre (mini-joystick is moved to the centre 'deadzone') or at the limit of the device range, i.e., the gamepad mini-joystick is essentially being used as a digital control in a manner similar to the keyboard.

The profiles of reports generated by both subjects while using the steering wheel are obviously different. The increased number of wheel reports for Player 5 versus Player 1 is a reflection of the fact that Player 5 took more time to complete the two laps while using the wheel, and thus generated more reports. In contrast to the gamepad data, the analog capability of the wheel is being utilized. The graph for Player 1, who had the fastest drive time for the wheel, shows a concentration of reports about the centre position of the wheel. In contrast, the graph for Player 5 shows a wider distribution of data, as they struggled to control the vehicle using the wheel, i.e., significant over steering.

This suggests that, although a more sensitive control method is a useful tool for a more skilled user, it is of little benefit to those of less skill. As few of the participants had much experience with steering wheels in games; this could explain the negative comments regarding the steering wheel, as they found it frustrating to use without the time to master. The distraction caused by this unfamiliar sensitivity could also go some way towards explaining the poor usability scores reported for the steering wheel. The analog nature of the brakes and pedals on the steering wheel controller allows the player to perform a variety of real-world rally driving techniques in a game such as the "heel-and-toe" and "left foot braking". However, none of the subjects in the study used these techniques.

This example shows the complexity involved in understanding a small aspect of user experience with game controllers. It highlights not only the need for greater understanding of user experience with game controllers, but also the need for parallel research of both functionality and usability in order to understand the interaction as a whole.

Overall, all three of the devices studied were able to support the game command functions, and the Steering Wheel was also able to transmit extra output using haptic feedback. Thus we may infer that for the game and devices studied, the game controller was working at 100%. However, the devices differed in the way the user interacted with them in the game. This study shows that the method of user interaction is actually an important aspect of game play, and how one may be able to assess its impact in a simple and direct laboratory evaluation. With experienced facilitators, a study such as this need not take more than two elapsed days.

5 Summary

To date, there has been little research conducted that examines the use of game controllers. In this chapter we described how McNamara and Kirakowski's (2006) theoretical framework can be applied to the evaluation of controllers in games. The subsequent user study conducted highlighted a number of issues relating to game controllers in terms of functionality, usability and user experience.

Much of on-going game-play testing that is performed as a regular part of the development process is accomplished using informal techniques. Such informal evaluation could also be complemented by more a structured evaluation of controller support, as outlined in the user study. It is relatively quick and easy to perform, and could be especially useful during the early stages of development to benchmark controller support.

5.1 Future Research

This user study was deliberately constrained in that it only explored the initial stages of game play for each of the controllers in a single game. However, with extended game play, the players will become more familiar with both the game and the controllers. As a result, longitudinal studies would be required to explore the issues that arise in the context of longer game play durations over an extended period of time. The same techniques applied in the user study could also be applied in the context of longitudinal studies, and the data then analyzed to explore change over time.

The data collected in the study consists of both data collect during game play (with logging software), and data collected afterwards as subjects complete questionnaires. The data collected during game play in the study was limited to the reports generated by the game controllers. It would be useful to complement this in-game data with biometric and video capture data (with emphasis on facial expressions and body movement). This could perhaps allow better interpretation of the in game reports, and complement the information collected post game play in the questionnaires.

Future studies should seek to elaborate on the effects of functionality on usability and experience. For instance, where possible, to observe the effects on game players in setups where the game controls, controllers, and support devices offer different levels of functionality as defined in this paper.

References

Adams E (2005) Bad Game Designer, No Twinkie! VI. Gamasutra Designer's Notebook. http://www.gamasutra.com/features/20050603/adams_01.shtml Accessed 23rd August 2008

Arnold A (1999) Mental Effort and Evaluation of User Interfaces: a questionnaire approach. The 8th International Conferance on Human-Computer Interaction. 1003-1007. ACM, NY

Atari Inc. (1977) Atari Stunt Cycle.

Albinsson P, Zhai S (2003) High precision touch screen interaction. Proc SIGCHI Conference on Human Factors in Computing Systems. ACM, NY

Bevan N, Mcleod M (1993) Usability Measurement in Context. Behaviour and Information Technology, 13, 132-145.

Brewster S, Faraz, C, Brown, L (2007) Tactile Feedback for Mobile Interactions. SIGCHI Conference on Human Factors in Computing Systems CHI 2007. 159-162. ACM, NY.

Brown M (2008) Evaluating Computer Game Usability: Developing Heuristics Based on User Experience. Proc. IHCI conference 2008. 16-21. University College Cork, Ireland.

Card S, English W, Burr BJ (1978) Evaluation of mouse, rate-controlled isometric joystick, step keys, and text keys for text selection on a CRT. Ergonomics 21, 601–613.

Codemasters (2007) Colin McRae: DIRT.

Csikszentmihalyi M (1975) Beyond Boredom and Anxiety. Jossey-Bass Publishers, London.

Cummings A (2007) The Evolution of Game Controllers and Control Schemes and their Effect on their Games. Proc 17th Annual University of Southampton Multimedia Systems Conference.

Dennerlein, J, Martin, D, Hasser, C (2000) Force-Feedback Improves Performance for Steering and Combined Steering-Targeting Tasks. CHI Letters 2 (1): 423–429.

Desurvivre H, Caplan M, Toth, JA (2004) Using heuristics to evaluate the playability of games. Extended Abstracts, Conference on Human Factors in Computing Systems. ACM Press, 1509-1512.

Falstein, N. and Barwood, H. The 400 Project. http://theinspiracy.com/400_project.htm Accessed 6th November 2008.

Federoff M (2002) Heuristics and usability guidelines for the creation and evaluation of fun in video games. Thesis. Indian University.

Flanagan J C (1954) The Critical Incident Technique. Psychology Bulletin, 51(4), 327-358.

Forlines C, Wigdor D, Shen C, Balakrishnan R (2007) Direct-touch vs. mouse input for tabletop displays. Proc SIGCHI Conference on Human Factors in Computing Systems 2007. 647-656. ACM, NY.

Forster W (2005) The encyclopedia of game machines - consoles, handheld and home computers 1972–2005. Hagen Schmid, Berlin.

Game Developer Magazine. http://www.gdmag.com/homepage.htm Accessed 8th November 2008

Graetz J M (1981) The origin of spacewar. Creative Computing, August 1981.

Hoysniemi J (2006) International survey on the Dance Dance Revolution game. Computer Entertainment. April 2006.

ISO (1998a) 9241 Ergonomic requirements for office work with visual display terminals (VDTs) - Part 9 - Requirements for non-keyboard input devices (ISO 9241-9).

ISO (1998a) 9241 Ergonomic requirements for office work with visual display terminals (VDTs) - Part 11 – Guidance on usability (ISO 9241-11).

Jørgensen A H (2004) Marrying HCI/Usability and computer games: a preliminary look. Proc. 3rd Nordic conference in HCI. 393-396.

Johnson D, Wiles J (2003) Effective affective user interface design in games. Ergonomics. 46, 13/14, 1332-1345.

Kane C (2005) Beyond the Gamepad
http://www.gamasutra.com/features/20050819/kane_pfv.htm accessed 20th October 2008.

Kavakli M, Thone J (2002) A Usability Study of input Devices on Measuring User Performance in Computer Games. Proc First International Conference on Information Technology and Applications 2002. 291-295.

Kent L S (2001) The Ultimate History of Video Games: From Pong to Pokémon. The story Behind the Craze That Touched Our Lives and Changed the World. Three Rivers Press.

Kirakowski J, M Corbet (1993) SUMI: the Software Usability Measurement Inventory. British Journal of Educational Technology. Blackwell Synergy.

Klochek C, MacKenzie I S (2006) Performance measures of game controllers in a three-dimensional environment. In Proc Graphics Interface 2006. Vol. 137., 73-79.

MacKenzie S (1992) Fitts' law as a research and design tool in human–computer interaction. Human–Computer Interaction 7, 91–139

Marshall D Ward T, McLoone S (2006) From chasing dots to reading minds: the past, present, and future of video game interaction. Crossroads 13, 2 (Dec. 2006), 10.

McCarthy J, Wright P (2004) Technology as Experience. The MIT Press. London.

McNamara, N. and Kirakowski, J. 2006. Functionality, usability, and user experience: three areas of concern. interactions 13, 6 (Nov. 2006), 26-28.

Nielsen, J. (1993) Usability Engineering. Academic Press Inc.

Pagulayan, R J, Keeker K, Wixon D, Romero R L, Fuller T (2003) User-centered design in games. In the Human-Computer interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications, J. A. Jacko and A. Sears, Eds. Human Factors and Ergonomics. L. Erlbaum Associates. Hillsdale, NJ, 883-906.

Pinelle D, Wong N, Stach T (2008) Heuristic evaluation for games: usability principles for video game design. ACM SIG CHI '08. 1453-1462.

Rabin I (2005) Introduction to Game Development. p125, Charles River Media.

Rubin J (1994) Handbook of Usability Testing. John Wiley & Sons, Inc.

Sheff D (1993) Game Over - How Nintendo Zapped an American Industry, Captured Your Dollars, and Enslaved Your Children. Random House, NY.

Silfverberg M, MacKenzie I S, Korhonen P (2000) Predicting text entry speed on mobile phones. Proc SIGCHI Conference on Human Factors in Computing Systems. CHI '00. ACM, NY, 9-16.