University Of KwaZulu-Natal

REAL-TIME STRATEGY GAMES AND TASK SWITCHING

By

Yusuf Ismail

207511342

A dissertation submitted in fulfillment of the requirements for the degree of

Master of Commerce in Information Systems and Technology

College of Law and Management Studies

School of Management, IT & Governance

Supervisor: Dr C. Blewett

Year: 2014

Declaration

I Yusuf Ismail declare that

(i) The research reported in this dissertation/thesis, except where otherwise indicated, is my original research.

(ii) This dissertation/thesis has not been submitted for any degree or examination at any other university.

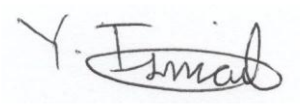
(iii) This dissertation/thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

(iv) This dissertation/thesis does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:

a) their words have been re-written but the general information attributed to them has been referenced:

b) where their exact words have been used, their writing has been placed inside quotation marks, and referenced.

(v) This dissertation/thesis does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the dissertation/thesis and in the References sections.

Signature: 

Acknowledgements

In the name of God, the Most Gracious, the Most Merciful.

I would like to thank all subjects who participated in this study, especially those who were selected to play the RTS video game over a period of time. Their time and efforts are greatly appreciated.

I would also like to express my heartfelt gratitude and sincere appreciation to my family, friends and my wife Fathima, for their prayers, continued support and understanding throughout this research project.

A big thank you goes to my supervisor, Dr. Craig Blewett, for his guidance, contributions and words of encouragement throughout this dissertation. A special thank you goes to Muhammad Jamal, for his assistance, enthusiasm and professional approach to statistical analysis.

"Seek knowledge from the cradle to the grave"

Prophet Muhammad (P.B.U.H)

Abstract

Numerous authors have examined the effects of video games on executive functions. This research focuses on the effects of video games on task switching, one aspect of executive functions. Switching between different tasks is a regular occurrence today and is an important skill to possess as people juggle between performing different tasks simultaneously in everyday life.

The effects of video game training on task switching has been continuously discussed and examined over time. This study aims to contribute to this debate by utilizing a Real-time Strategy (RTS) video game called StarCraft and measure its effect on the task switching performance of a population of video game players who do not play RTS video games, an area that the literature has not addressed.

The results of this study depicted that training in the RTS video game StarCraft had no effect on participants' task switching performance. Possible factors and particular aspects of the sample population were explored to explain this finding.

The factors that were identified included the configuration of StarCraft, the duration of the training schedule that participants undertook and possible interference from other video gaming activity. The problem of task-specific learning was also confirmed when using identical task switching test measures before and after video game training.

One aspect of the sample population identified was that the majority of participants may have reached their task switching performance potential through the numerous years of video game exposure. It was also hypothesized that RTS video game training has no impact on subjects' task switching performance who self-report being Indian.

Three video game genres were identified that could explain the superior task switching performance of subjects who self-reported being Coloured that participated in this study. Finally, the analysis revealed that the improvement in task switching performance exhibited by female StarCraft players were superior to the improvement demonstrated by male StarCraft players which suggests that RTS video games are better suited for improving females' task switching performance than males.

Table of Contents

List of Tables

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Chapter 5

List of Figures

Chapter 2

Chapter 3

Chapter 4

List of Abbreviations

AI :	artificially-intelligent
AVGP:	action video game player
AVGPs:	action video game players
CoD 2:	Call of Duty 2
FPS:	First-person Shooter
MoH:	Medal of Honor
nAVGP:	non-action video game player
nAVGPs:	non-action video game players
nVGP:	non-video game player
nVGPs:	non-video game players
PC:	personal computer
RoN:	Rise of Nations
RTS:	Real-time Strategy
UT 2004:	Unreal Tournament 2004
VGP:	video game player
VGPs:	video game players

Glossary of terms

Call of Duty 2:	A FPS video game developed by Infinity Ward and is the second instalment in the Call of Duty series (Infinity Ward, 2005)
Cognitive flexibility:	An individual's ability to think about multiple concepts simultaneously (Scott, 1962)
Executive functions:	A set of processes that all have to do with managing oneself and one's resources in order to achieve a goal (Cooper-Kahn & Dietzel, 2008, para. 4)
Medal of Honor: Pacific Assault:	A World War II based FPS video game developed by 2015 Inc. (2015 Inc, 2002)
Nintendo Wii:	A home video game console released by Nintendo in 2006
Non-playing RTS VGP:	A video game player who does not play Real-time Strategy video games
Playstation 3:	A home video game console produced by Sony Computer Entertainment, the third console in the Playstation series.
Rise of Nations:	A RTS video game developed by Big Huge Games that combines the speed of real-time gaming and complexity of turn-based strategy games (Basak, Boot, Voss, & Kramer, 2008; Big Huge Games, 2003)
StarCraft:	A military science fiction Real-time Strategy video game developed and published by Blizzard Entertainment (Blizzard Entertainment, 1999)
Task switching:	Concerned with an individual's ability to alternate between performing two or more tasks within a short period of time (Butler & Dee, 2012)
Tetris:	A tile-matching puzzle video game originally designed and programmed by Alexey Pajitnov (Pajitnov, 1984)

The Sims 2:	A Life Simulation video game developed by Maxis (Maxis, 2004)
Unreal Tournament 2004:	A futuristic FPS video game developed by Epic Games and Digital Extremes (Epic Games, Digital Extremes, Psyonix, & Streamline Studios, 2004).
Xbox 360:	A home video game console developed by Microsoft which is the second console in the Xbox series

Chapter 1 - Introduction

"Cognitive flexibility, a cornerstone of human intelligence, is not a static trait but can be trained and improved using fun learning tools like gaming. Previous research has demonstrated that action video games, such as Halo, can speed up decision making but Real-time Strategy games can also promote our ability to think on the fly and learn from past mistakes.

We need to understand now what exactly about these games is leading to these changes. Once we have that understanding, it could become possible to develop clinical interventions for symptoms related to attention-deficit/hyperactivity disorder or traumatic brain injuries, for example." (Glass, Maddox, & Love, 2013)

1.1 Introduction

In this chapter the two focus areas of this study will be introduced through a brief background and placed into context of this study. Thereafter, the need for this study will be established followed by a brief summary of this study's purpose. The questions that this study seeks to answer will then be postulated. Finally, an outline of this dissertation's structure will be provided.

1.2 Background and context

The video game industry has been steadily expanding with spending on games expected to reach $122 billion by 2015, according to a report released by Gartner (Bilton, 2011). The average person today who resides in a country with a strong gaming culture, would have spent ten thousand hours playing online games by the age of twenty one (McGonigal, 2010). An example of this phenomenon is evident in Activision Blizzard's flagship title World of Warcraft whose player base has collectively spent approximately six million years of total playing time as of 2010 since its release (McGonigal, 2010).

This vast amount of time invested by players in video games can be attributed to the evolution of video games since their inception. Early video games were much more abstract than the games developed today. An example of this is illustrated in a simple tile-matching puzzle video game called Tetris[1] which was released in 1984 (Pajitnov, 1984). Since then, video games' features have improved to now include three-dimensional graphics (NetherRealm Studios, 2011), co-operative play (Turtle Rock Studios & Valve Corporation, 2008), improved artificial intelligence (Frictional Games, 2011), enriched sound effects (Valve Corporation, 2011),

[1] Tetris is a tile-matching puzzle video game originally designed and programmed by Alexey Pajitnov (Pajitnov, 1984)

comprehensive storylines (Blizzard Entertainment, 2004) and realistic gameplay (The Sims Studio, 2009) amongst other aspects.

Video games include several genres which include action, strategy, simulation, adventure, role-playing and sports amongst numerous others (E. Adams, 2009; Crawford, 2011; Wolf, 2002). In strategy video games, players perform a series of tactical actions against one or more opponents to achieve victory (E. Adams, 2009; Pinelle, Wong, & Stach, 2008). The reduction of enemy forces is key to winning in many strategy games, resulting in most strategy games being war games (E. Adams, 2009).

A sub-genre of strategy games, called Real-time Strategy (abbreviated as RTS henceforth) exists, in which the goal is to secure areas of the game world that provide an advantage to the player and ultimately destroy their opponents' assets. The game environment is continuous and there are no pauses or breaks between players' actions. Players perform tasks and make decisions simultaneously while dealing with a constantly changing game state (Lara-Cabrera, Cotta, & Fernández-Leiva, 2013).

RTS video games are viewed from an aerial perspective which focuses on the game world rather than a single unit or character, a distinct difference from other video game genres (E. Adams, 2009). Hence, players see a larger part of the game world and several units or characters at once. The aerial view facilitates the selection of multiple units at once across the game's landscape. Groups of units can then be ordered to perform a set of tasks or a specific action (Pinelle, et al., 2008).

The gameplay of RTS video games involves players creating units, structures, researching new technologies and managing resources that are collected by specialized units and structures (Gunn, Craenen, & Hart, 2009; Pinelle, et al., 2008). Players create and assemble an army and eliminate opponents on a map setting that is based in real-time (Glass, et al., 2013).

In RTS video games, players must cope with added time pressures because all events occur without players getting individual turns to ponder their potential actions (E. Adams, 2009). To be successful in these video games, players must adapt to cope with game states that are in flux whilst thinking about potential decisions and reacting with speed to perform multiple tasks simultaneously (Glass, et al., 2013; Lara-Cabrera, et al., 2013). Some tasks that players perform throughout a scenario involve the management of resources, armies and making decisions based on intelligence gathered regarding their opponents (E. Adams, 2009; Glass, et al., 2013). RTS video games form the first focus area of this study and will be explored in more detail in chapter two of this dissertation.

Video game players (abbreviated as VGPs henceforth) devote significant portions of their time playing RTS video games as illustrated by StarCraft: Brood Wars, the most competitively played video game in 2010 (O'Neill, 2014). The increased usage in RTS video games and video games in general, has lead researchers to investigate the impact that video game experience has on human behaviour. Some aspects that have been investigated are the addictiveness of video games (Egli & Meyers, 1984; McClure & Mears, 1984), the negative effects of violent video games (Anderson & Bushman, 2001; Wiegman & van Schie, 1998), gender differences (Feng, Spence, & Pratt, 2007) and executive functions.

Executive functions can be described as a “set of processes that all have to do with managing oneself and one's resources in order to achieve a goal” (Cooper-Kahn & Dietzel, 2008, para. 4). The executive system in humans facilitate flexible behaviour to achieve a specific goal making coordination, control and goal-orientation fundamental in healthy executive functioning (R. Elliott, 2003).

The effect of video games on executive functions is a broad field that generally looks at motor skills (Griffith, Voloschin, Gibb, & Bailey, 1983; Orosy-Fildes & Allan, 1989), memory (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Ferguson, Cruz, & Rueda, 2007), learning (Blumberg, Rosenthal, & Randall, 2008; Green & Bavelier, 2012; Orvis, Horn, & Belanich, 2006; Pillay, 2002), problem solving skills (Blumberg, et al., 2008), spatial reasoning (Dorval & Pepin, 1986; McClurg & Chaillé, 1987; Quaiser-Pohl, Geiser, & Lehmann, 2006) and visual attention (Green & Bavelier, 2006, 2007; Greenfield, deWinstanley, Kilpatrick, & Kaye, 1994).

Boot, et al. (2008) claim that video games are more entertaining and engaging than traditional training methods. Thus researchers have examined the training effects of video games on various executive functions (Basak, et al., 2008; Boot, et al., 2008; Glass, et al., 2013; Green, Sugarman, Medford, Klobusicky, & Bavelier, 2012). Some developers have begun to market video games claiming that they improve specific executive functions as demonstrated by Nintendo’s Big Brain Academy video game (Nintendo, 2005).

The second area this study will focus on is task switching which is one aspect of executive functions. Task switching is concerned with an individual’s ability to alternate between performing two or more tasks within a short period of time (Butler & Dee, 2012). Meyer, et al. (1997, p. 1) define a task as “any activity in which systematic procedures must be applied to achieve a desired goal”. Switching between performing various tasks is a common occurrence in day-to-day living (Butler & Dee, 2012; Green, et al., 2012; Monsell, 2003).

Utilizing social networking applications while studying, cooking a meal whilst watching the news or driving whilst talking to a passenger and texting are all examples of task switching that can occur in everyday life (Butler & Dee, 2012). Moreover, improvements to technology allow many distinct tasks to be performed on a single device such as switching between reading an email, watching a video, speaking to a person via an instant messaging application and various other tasks that can be performed simultaneously (Green, et al., 2012).

Numerous factors have been identified that impact task switching performance. These factors include the presence of cueing (Rubinstein, Meyer, & Evans, 2001), gender (Criss, 2006; Halpern, 1986) and task complexity (Rubinstein, et al., 2001) amongst several others. With the surge in video game usage, its impact on task switching abilities has also been examined by myriads of researchers (Basak, et al., 2008; Boot, et al., 2008; Butler & Dee, 2012; Cain, Landau, & Shimamura, 2012; Colzato, van Leeuwen, van den Wildenberg, & Hommel, 2010; Glass, et al., 2013; Green, et al., 2012).

Having introduced the two focus areas of this research (RTS video games and task switching), the next section articulates the need for this type of study.

1.3 Motivation for this study

The debate on video games as a means of improving basic perceptual skills and cognitive abilities has been continuously discussed and examined over time (Boot, et al., 2008; Butler & Dee, 2012; Cain, et al., 2012; Clark, Lanphear, & Riddick, 1987; Colzato, et al., 2010; Frederiksen & White, 1989; Gopher, Well, & Bareket, 1994; Green, et al., 2012; Hart & Battiste, 1992; Karle, Watter, & Shedden, 2010). For example, the conclusion of a study on the effects of video games on executive functions showed that playing Donkey Kong and Pac Man improved the reaction times of older adults significantly when compared to those who did not play (Clark, et al., 1987). Another video game called Space Fortress was considered to be so successful, that it was incorporated into the training program of the Israeli Air Force (Boot, et al., 2008; Gopher, et al., 1994; Hart & Battiste, 1992).

However, recent studies have shown contrasting results. One such study concluded that students who reported playing higher amounts of video games per week had higher switching costs and took more time to switch between tasks (Butler & Dee, 2012). Many of the recent studies have examined the training effects of video games on non-video game players' (abbreviated as nVGPs' henceforth) task switching performance whilst others have compared the task switching abilities of VGPs to nVGPs. The current state of the literature on video games and task switching ability is clarified briefly in table 1.1 that follows.

Table 1.1 - Current state of the literature

Study	Outcome	Study	Outcome
Video game training studies		**Non-training video game studies**	
Boot, et al. (2008)	No evidence that suggests video game practice improves task switching performance (Boot, et al., 2008)	Colzato, et al. (2010)	First-person shooter (FPS) video games improve task switching skills (Colzato, et al., 2010).
Basak, et al. (2008)	Video game training has a beneficial effect on task switching ability (Basak, et al., 2008).	Cain, et al. (2012)	Experience in action based video games enhances task switching ability (Cain, et al., 2012).
Green, et al. (2012) (Experiment four)	Marginally significant positive effect on task switching performance (Green, et al., 2012).	Butler and Dee (2012)	Students who invest more time playing video games take longer to switch between performing different tasks (Butler & Dee, 2012).
Glass, et al. (2013)	RTS video game settings that promote rapid assessment and coordination across multiple sources of information enhances cognitive flexibility (Glass, et al., 2013).		

The outcomes of the studies listed in table 1.1, highlight the conflicting views on the effects of video games on task switching ability. This study aims to contribute to the ongoing debate on the benefit and ill-effects of video games on executive functions. All the studies in the literature investigating the training effects of video games on task switching performance used nVGPs in their samples. This study will contribute to the literature by examining the training effects of a particular genre of video games namely, RTS video games, on VGPs who do not play this specific genre of video games (non-playing RTS VGPs).

The need for determining the relationship between different video game genres and the nature of the transfers to executive functions has also been highlighted by various researchers (Basak, et al., 2008; Colzato, et al., 2010). Boot, et al. (2008) and Green, et al. (2012) have also accentuated the need for discovering the exact mechanisms and conditions that shape task switching abilities. This study will utilize a RTS video game in a specific setting to augment previous researchers' understanding about the effects of video games on executive functions.

In RTS video games, players are required to switch between performing various tasks and achieving several goals simultaneously as the demands of the game changes (Basak, et al., 2008; Boot, et al., 2008; Lara-Cabrera, et al., 2013). The constant switching between tasks in the game make it plausible to assume that RTS video games will improve players' performance in tests measuring executive functioning particularly, task switching (Basak, et al., 2008). This assumption further supports the application of a RTS video game in this study as a mechanism for improving task switching abilities.

One of the key goals of executive function training is to reduce or reverse the deterioration of cognitive functions especially in aging adults (Basak, et al., 2008; Colzato, et al., 2010). . Training in a video game could be an effective approach to compensate for losses in the aging populations ability to switch between tasks and respond to changing demands in a given situation which is an essential skill to possess in everyday behaviour (Colzato, et al., 2010). The outcomes of this study can generate additional guidelines on how RTS video games should be implemented for the purpose of improving task switching abilities.

The abovementioned facts support the need for this study. Exploring the reasons as to why particular video game genres affect task switching ability in the way they do, will assist in augmenting the knowledge base surrounding the effects of video games on executive functions. A comparison between the results of this study and others may also offer further insights into why RTS video games affect task switching abilities.

In this section the need for this type of study was established. The next section describes the intention of this study by presenting the statement of purpose and the research questions it seeks to answer.

1.4 Statement of purpose and research questions

1.4.1 Statement of purpose

The purpose of this study is to assess the impact of Real-time Strategy video games on non-playing Real-time Strategy video game players' task switching performance.

1.4.2 Research questions

- **What impact do RTS video games have on non-playing RTS VGPs' task switching performance?**

After training in a RTS video game for a predefined number of hours over a period of time, the video game will have one of three impacts on task switching ability. The first type of impact is a positive effect on task switching performance whereby participants' task switching performance improves after RTS video game training. The second type of impact is a negative effect on task switching performance where subjects' task switching performance deteriorates after training in a RTS video game over time. The third type of impact is no effect/difference or a marginal difference in task switching performance before and after RTS video game training. The hypotheses for this study are stated in table 1.2 that follows.

Table 1.2 - Hypotheses

Hypothesis	Statement
Null hypothesis (H0)	RTS video games have no impact on non-playing RTS VGPs' task switching performance
Alternative hypothesis (H1)	RTS video games positively influence non-playing RTS VGPs' task switching performance
Alternative hypothesis (H2)	RTS video games negatively influence non-playing RTS VGPs' task switching performance

The answer to this research question seeks to determine which effect RTS video games have on non-playing RTS VGPs' task switching performance after receiving training in an RTS video game for a predefined number of hours over a period of time.

- **Why do RTS video games impact task switching performance in the way they do?**

The answer to this research question seeks to understand why the observed effect on non-playing RTS VGPs' task switching performance is occurring. To explore the answers, the potential explanations arising from the methodological approach used in this study will be discussed. The data gathered from the sample which include demographical information and video gaming habits will also be examined to determine if any of these factors affect the impact that RTS video games have on non-playing RTS VGPs' task switching ability.

Having delineated this study's intention and the research questions that will be answered, the final section of this chapter will briefly outline the structure of this dissertation.

1.5 Structure of this dissertation

In chapter one a brief introduction of the two focus areas of this study was provided. The need for this type of study was also explained, followed by a brief summary of this study's purpose and the research questions it seeks to answer.

Chapter two will provide a comprehensive explanation of the two focus areas of this study (RTS video games and task switching) and review the work done by other researchers concerned with the effects of video games on executive functions to identify the gap that exists in the literature.

Chapter three provides a recap of the statement of purpose and the research questions this study seeks to answer. The research methods, techniques and decisions selected for this study will be described and justified here. A detailed description of each research instrument and a description of the manner in which they were implemented are also stipulated in this chapter. Finally, the ethical considerations and limitations of this study will also be addressed in chapter three.

In chapter four, the two research questions of this study are answered. This is done by presenting the findings gathered from the research instruments. These findings and their implications are analysed and explained in chapter four.

Chapter five presents a conclusion for this dissertation which revisits the purpose of this study. A summary of the key findings from this study will be provided in this chapter. Thereafter, recommendations for future research will be made. Finally, the fulfilment of this study's purpose and its contribution to the literature will be discussed.

Chapter 2 - Literature Review

2.1 Introduction

This chapter serves two purposes. The first is to provide a comprehensive elucidation of the two focus areas of this study: RTS video games and task switching. The second purpose of this chapter is to review the work done by other researchers concerned with the effects of video games on executive functions and to identify the gap that exists in the literature. The goal of this task is to establish the need for this study. Numerous authors have utilized video games for research. Some aspects that researchers have explored with video games are the addictiveness of video games (Egli & Meyers, 1984; McClure & Mears, 1984), the negative effects of violent video games (Anderson & Bushman, 2001; Wiegman & van Schie, 1998), gender differences (Feng, et al., 2007) and the effects of video games on executive functions.

This study focuses on a particular type of video game (RTS video game) and task switching, one of the many aspects of executive functions. First, video games in general will be examined, followed by comprehensive explanation of RTS video games (the first focus area of this study) and a brief description of the other video game genres this study is concerned with. Thereafter, the various aspects of RTS video games will be described in detail, to highlight the implications they have on this study and cognitive flexibility.

Next, research on the effects of video games on executive functions will be looked at briefly, followed by an explanation of executive functions and cognitive flexibility to foreground task switching (the second focus area of this study). Subsequently, task switching theory and its relationship to executive functions and cognitive flexibility will be explored. The outcomes of previous research conducted regarding the effects of video games on task switching will then be investigated. Finally, a gap that exists in the literature will be identified followed by how this study intends to fulfil this gap and contribute to the body of knowledge.

This chapter begins by focusing on how numerous experts define video games and what they entail. Because a specific type of video game (RTS video game) is mentioned throughout this study, a thorough understanding of what video games are will assist in placing RTS video games into context.

2.2 Video games defined

No formal definition exists for the term video game. Many authors have defined what video games are, based on their personal interaction with them and their understanding and interpretation of the concept. Simons and Newman (2004) solicited video game developers, writers, researchers and players about their interpretation of what video games are and recorded their responses in a chapter of a book entitled “Difficult Questions about Video Games”.

One such definition derived by Lisa Galarneau, a video game researcher, states that a video game is: “an interactive, graphically-enhanced experience involving exploration and play in a digital environment” (Simons & Newman, 2004, p. 12). While this definition may hold true for many video games, some games such as Tetris (Pajitnov, 1984) do not require exploration and may not be graphically enhanced. Carl Huber defines a video game as “entertainment that encourages and requires my input, can be enjoyed in a group, alone or online, and is digital” (Simons & Newman, 2004, p. 12). A plethora of definitions have been constructed by other authors that add to the debate of what constitutes a video game (Simons & Newman, 2004).

One video game researcher, Nicolos Esposito, claims that a video game is, “a game which we play thanks to an audio-visual apparatus and which can be based on a story” (Esposito, 2005, p. 2). The audio-visual apparatus that he describes refers to input devices such as a keyboards, mice or controllers and output devices such as speakers and screen. Hence there are varying levels of interactivity that occur between a player and the video game depending on the type of game and medium it has been designed for (Esposito, 2005).

Video games can be based on a story although many are not. Pac-Man is an example of an abstract game that is not based on a story (Funaki, 1981). However, video games like Square Enix’s Final Fantasy XIII contain rich back-stories and numerous cut-scenes to highlight important events (Kitase, 2010). Furthermore, in video games such as Bioware’s Mass Effect series, players are given the freedom to interact with other characters they meet in the way they wish, which have significant impacts on the final outcome of the game’s story (Bioware, 2007, 2010, 2012). The variety of options creates unique stories, encouraging players to replay the game and make different choices to witness the effects of their actions on the game’s outcomes. This feature enhances the replay value (potential for continued play after the game’s first completion) of video games.

In a report by Prato, Feijóo, Nepelski, Bogdanowicz, and Simon (2010), two dictionary definitions were chosen to explain the concept of a video game. Their first definition of a video game is, “an electronic or computerized game played by manipulating images on a video display or television screen” (Prato, et al., 2010, p. 17). Their second description of a video game is, “a game that can be played by using an electronic control to move symbols on the screen of a visual display unit” (Prato, et al., 2010, p. 17). Having been cited often and being the most recently acknowledged definition of video games by video gaming experts, their definitions of video games will be accepted and referred to throughout this dissertation.

Prato, et al. (2010) have also developed a model for the various video game components. These components are illustrated in figure 2.1 below, followed by a brief description of the essential components. Examining the various components of video games assists in explaining how video games are played, which is pivotal to this research.

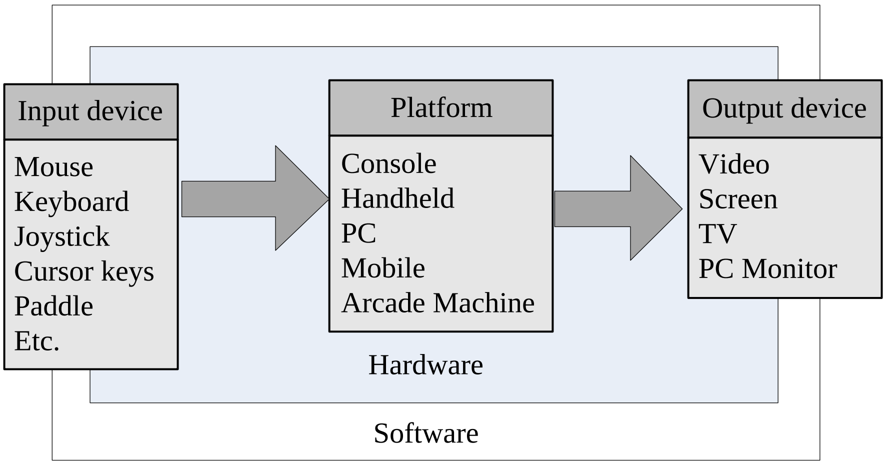


Figure 2.1 - Video game components (Prato, et al., 2010)

One or more tools that serve as input devices must exist to enable the user to control and interact with the game (Prato, et al., 2010). Video games are played on platforms such as consoles or personal computers because the game is controlled by software (Prato, et al., 2010). A television, video terminal or any form of screen is necessary as an output device (Prato, et al., 2010).

The explanation of input and output devices is not relevant to this study. However, the various platforms that video games are played on requires further exploration to expand the theoretical foundation surrounding video games and RTS video games.

2.3 Video gaming platforms

Video games can be played on numerous platforms. The "platform" refers to the hardware on which the video game is designed for (Apperley, 2006). Video games designed to run on consoles such as Microsoft's Xbox 360 and Sony's Playstation 3, usually render their outputs via liquid-crystal displays, light-emitting diodes and plasma displays. Most video games on these consoles are played with the use of a controller, where players push a combination of buttons and use a directional pad or analogue stick to control their characters actions in a video game. Some video games are played via a camera (called the Kinect for the Xbox and the Playstation Move for the Playstation 3) that records an individual's movements. Nintendo's Wii U is an example of a console that primarily focuses on movement and physical activity rather than input via controllers. The Wii possesses inferior graphics power than that of the Xbox 360, Playstation 3 and personal computer (PC), but compensates for this weakness with its excellent motion capture (Bakalar, 2009; Workman, 2010).

Handheld gaming devices such as the Nintendo DS and Sony's Playstation Vita are also successful mediums for which games have been developed. These devices are portable and can be used in any location. Pokémon is an example of a successful series that has been created for Nintendo's handheld devices (International Digital Times, 2013). Nevertheless, the smaller screens and weaker hardware specifications result in sound and graphics of lower quality when compared to other gaming platforms.

Other handheld devices such as tablets and mobile devices are now also being considered gaming platforms. Games such as Angry Birds and Temple Run have become popular on Apple's iPad, iPhone and other mobile devices (Carmichael, 2014). A player inputs commands in these types of games by touching, tapping or swiping the screen of the handheld device.

The PC offers the best graphical representations when compared to the other video gaming platforms resulting in video games that contain the most eye-catching scenery, visual details and realistic graphics. An example of the superior graphics on PCs can be seen in Bioshock Infinite (Irrational Games, 2013), which won the award for the PC game with the best graphics for year 2013 (IGN, 2013). Moreover, the limitations of the Playstation 3 and Xbox 360 consoles only permit the utilization of lower resolution textures resulting in inferior visual quality when compared to the PC (IGN, 2013; VanOrd, 2013).

Video games designed for PCs are most commonly played via a keyboard and mouse. Some video games on the PC are also designed to be played with a joystick, whilst others support the use of a controller. Furthermore, the introduction of the Oculus Rift (a virtual reality headset in development for 3D games on the PC) as an input device, could change the way video games are played (Garland, 2014).

In the previous sections, video games were defined and discussed in general. Thereafter, the various components of video games were described followed by the various platforms that they are played on. The next section addresses the various types of video games that this study is concerned with. RTS video games (one type of video game and the first focus area of this study), will first be examined thoroughly. Other studies concerned with the effects of video games on executive control have utilized a variety of video games in their studies which will be discussed in section 2.13 and 2.14 of this chapter. Thus, RTS video games will also be compared to the types of video games utilized in other studies to highlight how they differ. Furthermore, these types of video games are referred to in numerous discussions throughout this dissertation which merits further discourse on this area.

2.4 Video game genres

The concept of genres in video games has been a much debated topic amongst video gaming experts. Juul (2001) is one author who is resistant to any argument that challenges established video gaming industry categories. However, researchers such as Wolf (2002), argue in favour of a notion that a film-genre type classification be applied to video games.

Several experts on video game design claim that video games can be categorized based on gameplay and interactivity (E. Adams, 2009; Apperley, 2006; Wolf, 2002). Video games are classified without taking into consideration the game's plot or location in which the game's events occur (E. Adams, 2009). For example, a medieval strategy video game would belong to a different video game genre than a medieval role-playing video game.

Chris Crawford states that video game design is constantly changing and a taxonomy of video game genres at any point in time can quickly become obsolete (Crawford, 2011). In addition, he states that a correct taxonomy that is agreed upon by all is impossible to formulate. It is important to note that video games can belong to more than one genre as different types of actions and objectives can occur in a single game (Wolf, 2002). For example Star Wars: Rebel Assault, a game that belongs to the Shoot-em-up genre, features sequences that contain gameplay mechanics which can be categorized into other video game genres (LucasArts, 1993). This study will utilize the widely accepted industry standard of video game classification to explain the types of video games this study is concerned with.

The next section describes strategy video games in detail, particularly RTS video games (a sub-genre of strategy video games) which form the first focus area of this study.

2.4.1 Strategy

Strategy video games challenge the player to display tactical planning and perform a series of actions against one or more opponents to achieve victory (E. Adams, 2009; Pinelle, et al., 2008). The reduction of enemy forces is key to winning in many strategy video games, resulting in most strategy video games being war games (E. Adams, 2009). Superior planning and optimum action taking (be it logistical, economical, explorative or tactical) against opponents are pivotal in achieving victory (E. Adams, 2009).

However, not all strategy games focus on combat. An example is the game Tic-tac-toe (otherwise knows at Noughts and Crosses or X and O) in which two players take turns marking either an X (for player one) or O (for player two) in a three by three grid (Beck, 2002) and alternate, until a player succeeds in inserting their respective symbol in a vertical, horizontal or diagonal row (which results in a win for the respective player) or until all blocks have been filled (resulting in a draw) (Beck, 2002).

Strategy video games fall into two broad categories: turn-based or real-time. The strategy video games that are real-time based which will be discussed are Real-time Strategy video games, Multiplayer Online Battle Arenas and Tower Defences. Thereafter, turn-based strategy video games will be described briefly. The next sub-section offers a comprehensive discussion on Real-time Strategy video games.

- **Real-time Strategy (RTS)**

A player's goal in RTS video games is to secure areas of the game world that provide an advantage to the player and ultimately destroy opponents' assets. Players must learn to cope with time pressure because all events occur without players getting individual turns to ponder their potential actions (E. Adams, 2009). The state of the environment is continuous and there are no pauses or breaks between players' actions. As a result, players are required to think and react quickly as they perform several tasks and make decisions simultaneously (E. Adams, 2009; Lara-Cabrera, et al., 2013). Players do this while dealing with a constantly changing game state.

RTS video games require players to oversee a large number of units (Pinelle, et al., 2008). The game is viewed from an aerial perspective which focuses on the game world rather than a single unit or character (E. Adams, 2009). This enables the player to see a larger part of the game world and several units or characters at once. Furthermore, the aerial view facilitates the selection of multiple units at once across the game's landscape which in turn can be ordered to perform a set of tasks or a specific action (Pinelle, et al., 2008).

The gameplay of RTS video games is characterised by the creation of units, structures and research of new technologies which is directly associated with the management resources which are collected by specialized units and structures (Gunn, et al., 2009; Pinelle, et al., 2008). With these resources, players create, assemble and command an army against an opponent in a map setting that is real-time based (Glass, et al., 2013). To be successful, players must adapt to cope with game states that are in flux whilst simultaneously managing available resources and making decisions based on intelligence regarding their opponents (Glass, et al., 2013; Lara-Cabrera, et al., 2013).

Other gameplay characteristics that distinguish RTS video games from other genres are micro-management and macro-management (Lara-Cabrera, et al., 2013). Micro-management in RTS video games involves the player controlling a small number of units and giving them specific orders (Lara-Cabrera, et al., 2013). Macro-management involves managing large quantities of tasks simultaneously such as building new structures whilst at the same time scouting with units (Lara-Cabrera, et al., 2013). These micro and macro-management actions are often performed simultaneously, hence rewarding players with better task switching skills.

Blizzard Entertainment's StarCraft is an example of a popular and balanced RTS video game where no strategies and tactics are unfair or unbeatable (Purchese, 2010). Video game reviewers have highlighted it as one of the most successful games of all time and one that set the standard of how video games in its genre should be developed (Edge, 2007; Fatt & Gamepro, 2007). A screenshot of its user interface is depicted figure 2.2 that follows. The key elements on screen that players give attention to are highlighted in blue rectangles. These elements are described in table 2.1 thereafter.

Figure 2.2 - StarCraft user interface (Blizzard Entertainment, 1999)

Table 2.1 - StarCraft user interface described

Area	Description
A	These numbers display the player's available resources: Minerals (number adjacent to the blue symbol), Vespene Gas (number adjacent to the green symbol) and current population limit (number adjacent to the white symbol). The population limit constrains the size of a race's army. The limit can be increased to a maximum of two hundred by producing the appropriate units or structures. New units may be produced as long as the cumulative control (in the case of the Zerg race), supply (in the case of the Terran race) or "Psy" (in the case of the Protoss race) of all active units does not exceed the number of available control/supply/psy counters. The first number of the population limit (x) refers to the control/supply/psy used and the second number (y) is the total available control/supply/Psy.
B	This area provides a detailed view of the currently selected area on the mini map. The terrain, resource nodes, units and structures can be seen and selected in this area.
C	This section contains the mini-map. The mini map shows an overview of the entire area for a particular level. The small white box on the mini map indicates the area of the game world that is currently being displayed in area B. Players may select different areas of the mini-map to have those areas of the game world displayed on screen.
D	This area highlights selected unit/s current status. Remaining health, shields, energy (used to perform abilities) and equipped technologies are displayed. Knowing the current status of troops assists the player in making strategic and tactical decisions.
E	The commands that can be issued to the currently selected unit/s are located here. Although default commands can be issued by clicking on an object in area B, some specialized tasks such as holding position or patrolling a certain area can only be issued by clicking on the appropriate command in this area or by using hotkeys).

The following sections briefly explain Multiplayer Online Battle Arenas and Tower defences which are also real-time based.

- **Multiplayer Online Battle Arenas (MOBA)**

Also known as Action Real-time Strategy, this sub-genre of RTS video games involves two teams of players who compete against each other. Although these video games implement a RTS-type user interface there are key differences to note. There is no unit construction or resource management and players control only one character. The game emphasizes teamwork and cooperative gameplay. Each player selects a hero, a powerful unit with unique abilities at the beginning of each scenario. Together, a team must synergize their heroes' abilities to destroy their enemy team's main structure with the aid of periodically spawned computer-controlled units called "creeps". These creeps march towards the enemy's main structure via predefined paths called "lanes".

- **Tower Defence**

These video games have simple layouts and involve computer-controlled enemies called "creeps" that move along a set path. The goal of the game is to hamper creep movement and eventually kill them by building defensive structures or towers along the path. Defeated enemies reward the player with gold or some other form of currency, which can be used to upgrade existing towers or construct new ones. When a monster clears the path without being killed it is referred to as a "leak". When a player leaks, life is deducted from their life total. The game ends when all levels are cleared or when a player's life is reduced to zero.

Turn-based strategy games will now be discussed as outlined.

- **Turn-based Strategy**

These strategy games require players to follow a game-playing sequence (Gunn, et al., 2009). Turn-based strategy games require a great deal of strategic thinking as players are granted time to analyse the game state, ponder over potential actions and consider one choice over the other to make the best decisions whilst the others wait their turn (E. Adams, 2009; Gunn, et al., 2009).

The previous sections have analysed strategy video games, in particular RTS video games in detail. The other video game genres that are relevant to this study will now be examined. Video game taxonomy includes strategy, action, simulation, adventure, role-playing, sports and other genres (E. Adams, 2009; Crawford, 2011; Wolf, 2002). The various video game genres that this study is concerned with are illustrated in figure 2.3 that follows. Additionally, the focus area of this study (Real-Time Strategy games) has been indicated in bold in addition to the video game genre that will be examined next: action based video games. As indicated before, action based video games have been utilized in other studies and mentioned in numerous places throughout this dissertation, necessitating further elaboration on this video game genre.

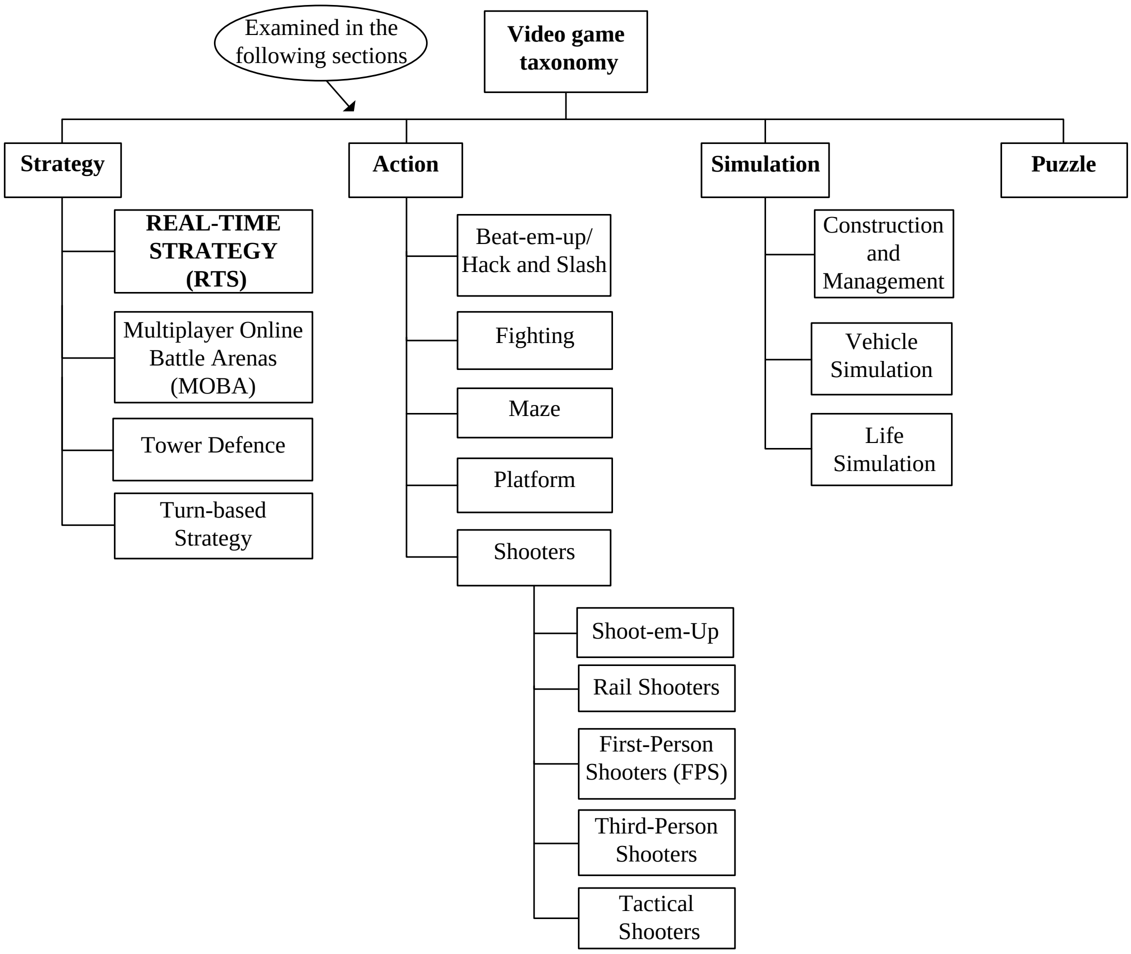


Figure 2.3 - Video game taxonomy (Action indicated)

2.4.2 Action

These video games are usually fast-paced and the majority of challenges presented to players test physical skills and coordination (E. Adams, 2009). Players usually control one character (Gunn, et al., 2009) and are rewarded for displaying rapid reflexes, making the correct snap decisions, accuracy, timing and in many cases the ability to perform combo moves (actions performed in sequence with time limitations that yield significant advantages) (E. Adams, 2009; Gunn, et al., 2009; Pinelle, et al., 2008). The gameplay elements of action games emphasize combat.

- **Beat-em-up/Hack and slash**

These video games emphasize one-on-many close quarters combat in which players "beat up" a significant number of computer-controlled enemies. Players are required to complete a series of levels with each subsequent level becoming increasingly difficult. Beat-em-up games involve hand-to-hand combat whilst Hack and Slash games involve the use of melee weapons, especially bladed weapons.

- **Fighting**

These video games emphasize one-on-one combat. A player's opponent may be computer-controlled or played by another person. Characters perform actions and occasionally physically impossible movements by linking together long chains of pre-defined button combinations (E. Adams, 2009).

- **Maze**

The playing field in these games usually consist of a maze in which players need to explore while avoiding monsters or other players that will attempt to obstruct the player's way. The most famous game in this genre to date is Pac-Man. This video game requires the player who controls an avatar called Pac-Man, to move through or "eat" all the white dots called pellets in the maze to advance to the next level whilst avoiding the monsters which roam around (Funaki, 1981). If a monster touches the player's avatar, a life is lost. Once all lives are lost, the game ends (Funaki, 1981).

- **Platform**

These games require players to travel between platforms at different heights by jumping, swinging, bouncing or climbing ladders whilst avoiding obstacles and battling enemies to reach the end of a level. The player's character usually possesses supernatural jumping capabilities and cannot be harmed by falling long distances (unless by falling into an obstacle) (Funaki, 1981). Platform games utilize unrealistic physics, as players are granted the ability to change their character's direction in mid-air (Funaki, 1981).

The most renowned two dimensional (2D) side-scrolling platform game to date is Super Mario Bros (Nakago, Morita, & Nishida, 1985). Conflicts in these types of games are non-violent. For example, in Sonic the Hedgehog, players simply jump on enemies to "attack" them and when touched, they simply disappear (Sonic Team, 1991).

Three dimensional (3D) platform games allow movement in all directions. However the 3D environment introduces new complications such as making it more difficult to judge the distance from the character that the player controls which is essential in these games (Funaki, 1981). These issues result in more complicated and difficult game controls (Funaki, 1981).

- **Shooters**

Shooters focus on combat requiring players to take actions from a distance using ranged or projectile weapons such as guns and missiles (E. Adams, 2009). Aiming is therefore an essential skill needed to progress, especially in games that provided limited ammunition (E. Adams, 2009). These games are divided in to many sub-categories depending on the camera perspective they are played from.

  - **Shoot ’em Up**

The encounters in Shoot’ em Ups or arcade shooters are 2D and take place in a setting which is viewed from either a top-down angle or side-view (E. Adams, 2009; Wolf, 2002). The events that occur in Shoot ‘em Ups contain unrealistic physics. Examples of these unrealistic physics are illustrated in projectiles that move in straight lines and constant speeds which are unaffected by gravity (E. Adams, 2009). Additionally, all vehicles, ships and other objects can change direction instantaneously (E. Adams, 2009).

In these video games, players control a character, spaceship or vehicle. The main objective is to shoot down a large number of enemies while dodging enemy fire, incoming obstacle and projectiles (E. Adams, 2009; Feldman & Feldman, 2001; Wolf, 2002). At some points there are an overwhelming number of enemies to destroy and dangers to avoid which require the player to display fast reaction times and memorization of enemy patterns (E. Adams, 2009; Feldman & Feldman, 2001; Wolf, 2002). Ammunition is usually infinite (except for the most powerful types of weapons), allowing the player to shoot at will (E. Adams, 2009; Wolf, 2002). Thus the game emphasizes destroying as many enemies as possible.

The remainder of the sub-genres of shooting games listed are all 3D. 3D shooters make extensive use of gaming hardware, resulting in eye-catching environments (E. Adams, 2009). The environments in 3D games are plausible and are used to greater effect to present more difficult challenges than 2D games. Additionally, the physics that occur are much like the real world (E. Adams, 2009). Gravity also functions as it would in the real world such as objects that cast shadows under environmental effects and collisions are that are modelled with accuracy (E. Adams, 2009).

Furthermore, the volume of sound effects will vary as the distance changes between the player’s character and the object projecting the sound (E. Adams, 2009). Finally, the landscape can also be altered as it responds to environmental shocks, explosions and other events (E. Adams, 2009). These additional features result in 3D shooters being much more realistic than 2D shooters.

However, there are a few advantages 2D games hold over 3D games. For example in a 3D game, players may not be able to judge the speed or distance of an object that comes directly towards their point of view (E. Adams, 2009). The side or top-down view in 2D games enable the player to correctly judge the distance between their character and obstacles including the speed of incoming objects and projectiles as they are moving (E. Adams, 2009).

- **First-person Shooters (FPS)**

Commonly abbreviated as FPS, these games follow a single character and emphasize shooting (with firearms) and combat from a distance from the perspective of the character that the player is controlling (Garmon, 2005; Pinelle, et al., 2008). Players collect a range of different weapons to use and move through the game's world whilst shooting enemies (Pinelle, et al., 2008). Fair aiming skills are of vital importance in these games. The events that transpire are usually fast-paced and require quick reflexes especially on higher difficulty levels or against skilled opponents.

- **Rail Shooters**

Rail shooters are a sub-genre of first-person shooters. Exploration in these games are uncontrollable or in some cases limited (E. Adams, 2009). Events occur as tactical objectives in enclosed environments and the game progresses by moving the player's view and position from one point of the game world to the next.

- **Third-person Shooters (TPS)**

Abbreviated as TPS, these games also emphasize shooting and combat from a distance but from a camera viewpoint at which the player's character can be viewed from a distance. This camera angle gives the player a wider view of their character's surroundings as opposed to the limited viewpoint in FPS video games. TPS video games utilize this wider viewpoint by enabling the player's character to perform elegant movements such as diving and rolling and greater interaction with environmental objects, such as hiding behind boulders or walls for cover. Many games such as Mass Effect 3 (Bioware, 2012) allow the player to play through the game in both first and third-person viewpoints.

- **Tactical Shooters**

Tactical shooters allow players to switch between different characters in a squad or team and can be played from either a first or third-person perspective (Pinelle, et al., 2008). These games focus on realism which sets players' characters in lifelike situations whilst offering a choice of realistic weapons (E. Adams, 2009). Tactical actions assume a large role in the game which includes planning, teamwork, coordination, specialized roles, stealth and cover. Teams in these video games simulate modern-era Special Forces and players assume the role of squad members where they work together to overcome challenges (players command a squad of artificially intelligent controlled characters in addition to their own in single player mode) (E. Adams, 2009). Missions are often completed by holding or capturing an objective rather than killing the most enemies.

Having discussed action based video games, the next sub-section emphasizes the differences between these types of video games and RTS video games. These differences are highlighted to further justify the utilization of RTS video games in this study as a tool for improving task switching abilities rather than action based video games.

- **Differences between action based video games and RTS video games**

From the previous sections, various differences can be noted between action based video games and RTS video games. Action based video games emphasize timing and hand eye-coordination whereas RTS video games do not (E. Adams, 2009). Furthermore in most cases, players control only one character at a time, a distinct difference to RTS video games. In RTS video games players constantly assign varying tasks to numerous types of units on the battlefield that fulfil various roles.

Another key difference between action based video games and RTS video games lies in the interaction and camera model (the concepts of interaction and camera models are addressed in section 2.8.1 and 2.8.2 of this chapter). In action based video games, players are required to focus on the immediate surroundings of their character only via a first or third-person perspective (E. Adams, 2009; G. King & Krzywinska, 2002). In RTS video games a top-down perspective camera model is utilized, and players are obligated to be aware of events that occur within the game world that are not currently visible on screen (E. Adams, 2009; G. King & Krzywinska, 2002).

Players are granted the ability to switch their view to display different parts of the game world via the mini-map and issue commands to units and objects that reside there (E. Adams, 2009; G. King & Krzywinska, 2002) (see figure 2.2 of a graphical representation of a mini-map of the RTS video game StarCraft). This places more cognitive load on players than action based video games because players need to perform actions and make decisions across multiple information sources (Glass, et al., 2013).

Having examined strategy and action based video games in detail, the next video game genre that this study is concerned with is Simulation. Figure 2.4 that follows pinpoints this video game genre which will now be discussed.

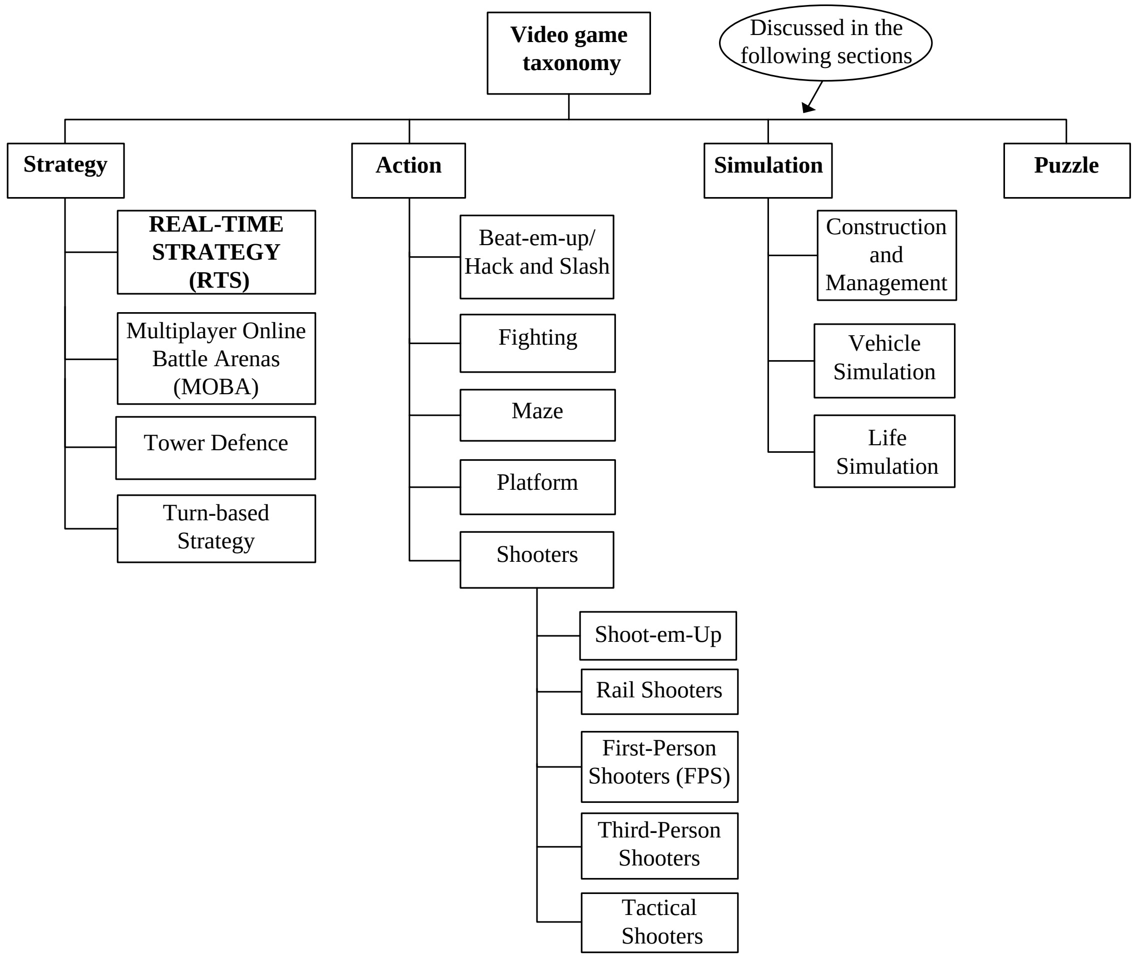


Figure 2.4 - Video game taxonomy (Simulation indicated)

2.4.3 Simulation

Simulation video games are designed to simulate aspects of reality such as the simulation of driving, flying, sports, dynamics in communities, towns and cities (Apperley, 2006) The simulation video games that will be looked at are: Construction and Management Simulation, Vehicle Simulation and Life Simulation.

- **Construction and Management Simulation**

In these simulation games, players build, maintain and expand fictional projects with limited resources (Wolf, 2002). The goal is to build and maintain an entity rather than defeating an enemy (E. Adams, 2009). These games include economic challenges where the concepts of constructional activities and growth are essential (E. Adams, 2009). A successful game that has been developed in this sub-genre of Simulation video games is SimCity 3000, where players are tasked with constructing a city, maintaining it and keeping citizens happy whilst adhering to strict budget constraints (IGN, 1999; Kasavin, 1999; Maxis, 1999).

- **Vehicle Simulation**

Vehicle Simulations attempt to provide players with a realistic experience of driving a vehicle or flying an aircraft (E. Adams, 2009; Howland, 1999). The environments these vehicles are driven in include land, air, sea or space (E. Adams, 2009). The main challenge in these games is to master and perfect how to operate the vehicle (Howland, 1999). Other challenges include races against other players or computer-controlled opponents (E. Adams, 2009). An element found in these games is verisimilitude, where players seek an experience in a way that the vehicle is driven or the aircraft is flown in reality (E. Adams, 2009). An example of game in this sub-genre is Microsoft’s Flight Simulator series (Microsoft Game Studios, 2006).

- **Life Simulation**

In Life Simulation games, players are granted the ability to control virtual living organisms, creatures or people (E. Adams, 2009). In digital pet life games, players foster, grow and train simulated animals (E. Adams, 2009). An example of digital pet life games is illustrated in the Tamagotchi.

In social life simulation games such as The Sims, players manipulate social interactions between artificial lives (E. Adams, 2009). In The Sims, these virtually created people are referred to as Sims (Maxis, 2000, 2004; The Sims Studio, 2009). In this video game, players are tasked with ensuring that their Sims basic needs are met (Maxis, 2000, 2004; The Sims Studio, 2009). This is accomplished by players instructing their Sims to acquire a job or attend school whilst building them shelter, buying useful household items and creating relationships with other Sims (Maxis, 2000, 2004; The Sims Studio, 2009). Although the game does not offer any explicit goals, players can play the game in the way they wish (E. Adams, 2009). For example, players can attempt to reach their Sims aspirations or just build large mansions with the best luxuries once they have acquired the necessary funds.

Finally, Life Simulation video games also include god-type games, where players use divine intervention and supernatural powers to influence a population of worshippers (E. Adams, 2009). An example of a god game is the Populous series developed by Bullfrog (Bullfrog, 1991).

The previous sections have examined Simulation video games. The difference between these types of video games and RTS video games will be addressed in the next sub-section to justify the use of RTS video games in this study as opposed to Simulation video games.

- **Differences between Simulation video games and RTS video games**

The primary difference between Simulation video games and RTS video games is that players do not have to cope with time constraints in Simulation video games. Although there are no pauses between actions, simulation video games are usually slow paced video games where players have more time to decide on future activities (Green, et al., 2012).

Warfare and conflict are common in RTS video games. Players will often react to intelligence gathered or enemies' attacks resulting in less time to ponder about potential actions. Furthermore, the rapid task switching in RTS video games is unseen in Simulation video games. Hence, RTS video games are better suited to players who are skilled task switchers as they reward players with fast reaction times and efficient task switching skills.

Strategy, action and Simulation video games have been discussed thus far. The final video game genre that this study is concerned with is Puzzle video games. Figure 2.5 below indicates the final video game genre that will now be reviewed.

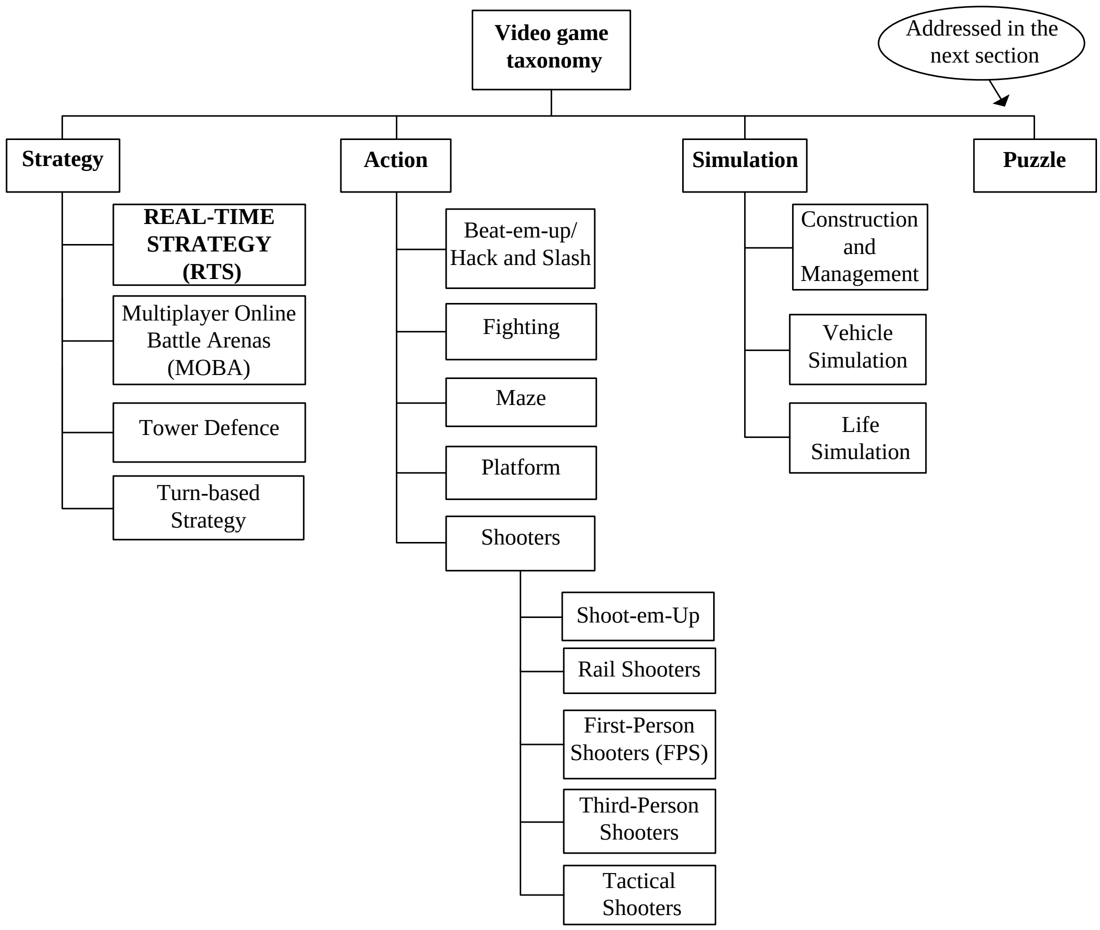


Figure 2.5 - Video game taxonomy (Puzzle indicated)

2.4.4 Puzzle

The primary activity in Puzzle video games is problem solving (E. Adams, 2009). The challenges in these games include pattern recognition, understanding of a process and making logical deductions (E. Adams, 2009; L. Elliott, Golub, Ream, & Dunlap, 2012). The player is offered clues that provide hints on how to solve the puzzle to meet the winning conditions (E. Adams, 2009). Players may also need to unravel these puzzles under time constraints which require quick reflexes (E. Adams, 2009; S. Miller, 2010). An example of a Puzzle video game involving time constraints is Tetris (E. Adams, 2009; D. King, Delfabbro, & Griffiths, 2010; Pajitnov, 1984). However, E. Adams (2009) argues that it inherits mostly action based video game properties because the game requires more physical coordination than logical problem solving.

The previous section has briefly described Puzzle video games. Like the other video game genres discussed, this type of video game will now be compared to RTS video games to justify the use of RTS video games in this study over Puzzle video games.

- **Differences between Puzzle video games and RTS video games**

Based on various authors' descriptions of the activities associated with Puzzle video games, it is clear that limited (if any) task switching occurs. Puzzle games may be viable tools for improving and developing other executive functions when played under time constraints, since fast thinking and problem solving skills are required to win.

Having examined the video game taxonomy that is relevant to this study, the model of the gameplay mode created by E. Adams (2009) will now be explored in detail. E. Adams (2009) is regarded as one of the leading experts in video game design as demonstrated by the numerous works he has produced over an extended period of time (E. Adams, 2009, 2013; E. Adams & Dormans, 2012; Rollings & Adams, 2003).

E. Adam's (2009) model encompasses various aspects of all video games. Each aspect will be examined in detail and related to RTS video games to further explain the activities that players perform within RTS video games and the extent of the cognitive load they place on players.

2.5 Gameplay mode

E. Adams (2009) defines the gameplay mode as the gameplay and supporting user interface at any given point in time in the game. Figure 2.6 that follows illustrates the gameplay mode of a video game and all the aspects that it encompasses.

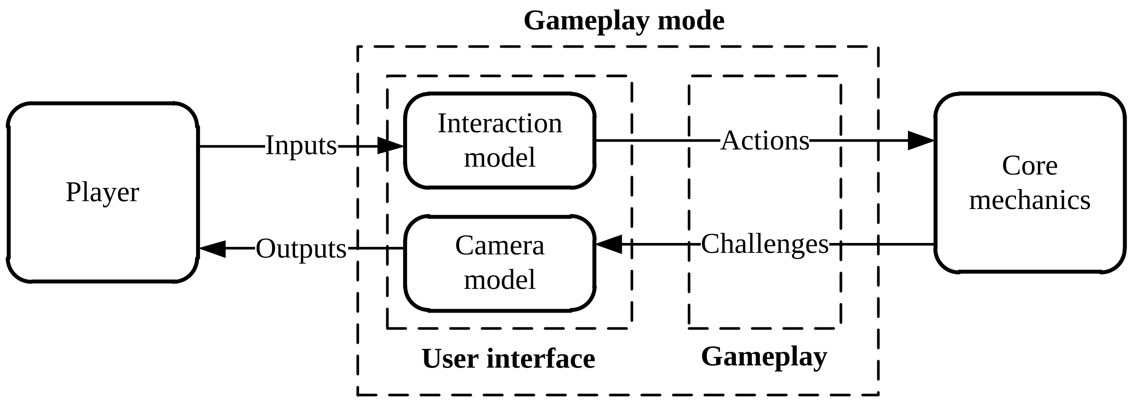


Figure 2.6 - Gameplay mode (E. Adams, 2009)

The gameplay mode consists of the user interface and the gameplay of a video game as portrayed in figure 2.6 above. The figure depicts that the gameplay of a video game consists of the challenges that are presented to the player and the actions that a player is permitted to take to overcome those challenges (E. Adams, 2009). Furthermore, the user interface comprises of the interaction and camera model (E. Adams, 2009).

In a given gameplay mode, all these components combine to give the player an experience that is different from other parts of the game (E. Adams, 2009). A video game can only be in one gameplay mode at a time and when the gameplay, user interface or both change significantly, the game enters another gameplay mode (E. Adams, 2009). The gameplay modes of StarCraft are stipulated in appendix C.

The first aspect of the gameplay mode that will be inspected is the gameplay of a video game. As stated earlier, this is done to further explain the activities that players perform within RTS video games such as StarCraft and the extent of the cognitive load each aspect places on players. The gameplay of a video game will first be defined followed by the discussion of the two aspects that the gameplay comprises (challenges and actions).

2.6 Gameplay

Over the years, numerous authors have derived definitions for the term gameplay in video games. Some of these definitions have been derived in a player independent manner. A notion of what gameplay is has been developed by successful game designer Sid Meier (known for his Civilization series (Wade, Kipp, & Beach, 2010)) which is “a series of interesting choices” (Rollings & Morris, 2000, p. 38). A later explanation developed which describes gameplay is, “one or more causally linked series of challenges in a simulated environment” (Rollings & Adams, 2003, p. 201). Other authors have hinted at more player-centered definitions such as those described by Fabricatore (2007) and E. Adams (2009). According to Fabricatore’s (2007) research, VGPs focus on the gameplay when determining the quality of the game. As such, player-centered definitions of gameplay will be used to discuss the concept of the gameplay in RTS video games in this dissertation.

Fabricatore (2007) describes gameplay as the actions the player is capable of performing and what actions other entities are able to do in response to the player's actions. E. Adams (2009) articulates that gameplay consists of "the challenges that a player must face in order to arrive at the object of the game" (E. Adams, 2009, p. 11) and "the actions that the player is permitted to take to address those challenges" (E. Adams, 2009, p. 11).

In StarCraft, the gameplay revolves around moving and manipulating units around the map, finding and gathering resources, building an army, researching upgrades and technologies and finally, attempting to destroy an opponent's assets who will be performing similar activities, attempting to do the same (Rouse, 2004).

The definition constructed by E. Adams (2009) will be divided into two parts and be discussed in further detail. The first aspect of his definition is "the challenges that a player must face in order to arrive at the object of the game" (E. Adams, 2009, p. 11). This first aspect will be addressed in the next section (depicted in figure 2.7 below) to demonstrate the cognitive load that the gameplay challenges of RTS video games places on players.

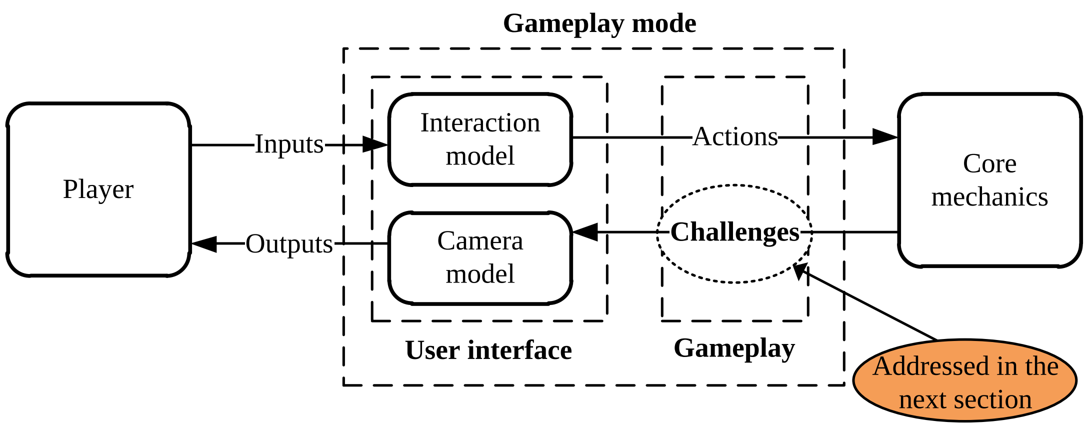


Figure 2.7 - Gameplay mode (challenges indicated) (E. Adams, 2009)

2.6.1 Gameplay challenges

People enjoy challenges as long as they have a reasonable expectation of overcoming them (E. Adams, 2009). Even if there is little to no expectation of overcoming a particular hurdle, players will still attempt to surmount it if the risk is low and reward is high (E. Adams, 2009). This makes the presentation of challenges a fundamental aspect of video games, as players enjoy proving that they can overcome them (E. Adams, 2009).

Challenges presented in games are of two types: implicit and explicit. Challenges that the video game informs the player about are explicit and are obstacles intended by the game designer (E.

Adams, 2009). Challenges that emerge from the game design and discovered by the player are implicit (E. Adams, 2009).

For example in a RTS video game, the explicit challenge or victory condition presented to the player is to destroy all units and structures belonging to the enemy. The most straightforward strategy would be to produce units that are capable of eliminating the opponent's units and structures one by one. Resource management and production systems are included in RTS video games and it is possible that the opponent is capable of producing units faster than the player can destroy them. An effective strategy to winning in this scenario is to protect one's production supply whilst disrupting the enemy's so the player can eventually overwhelm the opponent with superior numbers. This is the intrinsic challenge that arises from the video game's design.

E. Adams (2009) provides a detailed description of the most commonly used challenges presented in video games. Some of these challenges are common across numerous video game genres. Figure 2.8 below lists the types of gameplay challenges and appearances in RTS video games. Additionally, the first type of challenge (physical coordination challenges) that will be examined is indicated.

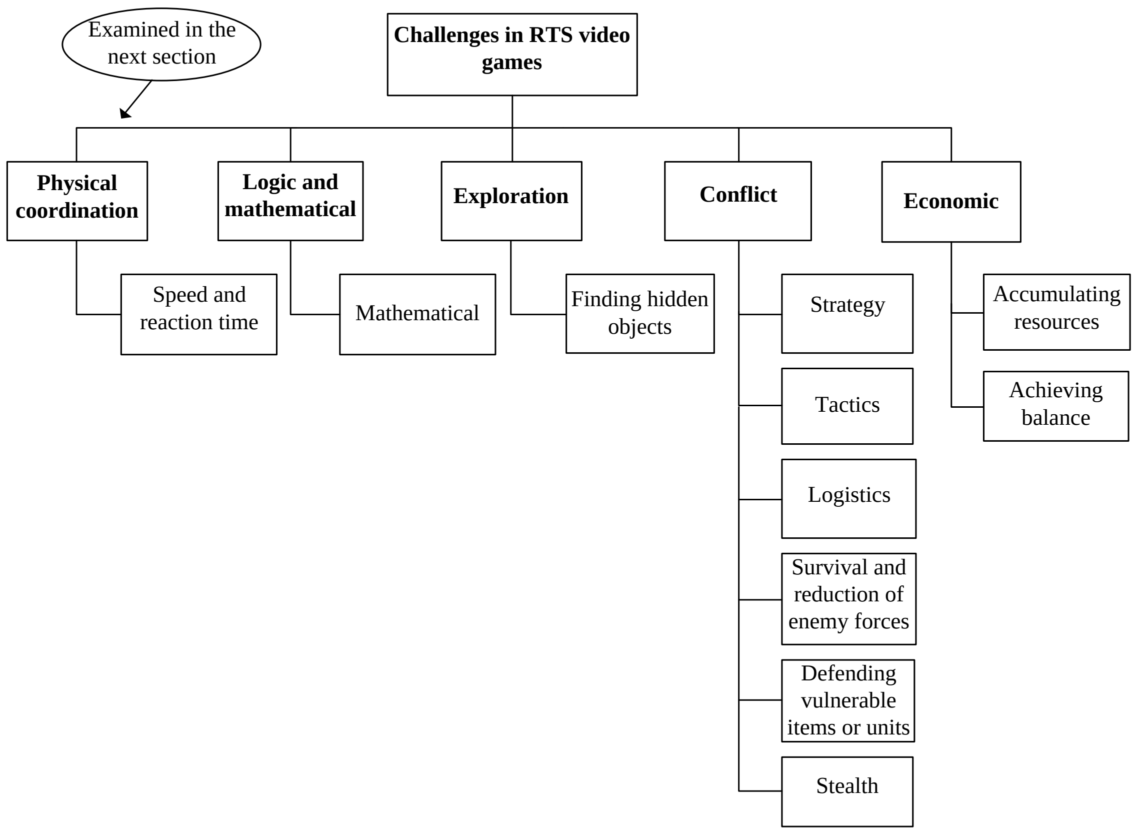


Figure 2.8 - Challenges in RTS video games (physical coordination indicated)

- **Physical coordination challenges**

These challenges test the player's physical abilities. Physical coordination remains a basic component of arcade gaming and forms a significant part of most video games produced today (E. Adams, 2009). The more time a player is given to complete a challenge, the easier it becomes. Similarly, limited time periods with which to complete physical coordination challenges increase the difficulty. Hence the difficulty of physical coordination challenges is directly related to the amount of time given to the player to overcome them (E. Adams, 2009).

  - **Speed and reaction time**

Speed and reaction time challenges test the player's ability to input the correct commands as quickly as possible (E. Adams, 2009). Reaction time tests the player's ability to react as quickly as possible to events (E. Adams, 2009). Speed and reaction time are important skills required in action games, particularly FPS video games.

Professional StarCraft VGPs demonstrate extremely quick reaction times (Thompson, Blair, & Henrey, 2014). For example, a player may quickly manoeuvre their units into position as they respond to information recently gathered about their opponent's actions. In another example, a player's assets that are not currently visible on screen (because they reside in other locations of the game world) can be attacked by their opponents. With fast reaction times a player can navigate to the appropriate area of the map, select those units and issue the most optimal commands to them before they are killed. Hence, RTS video games encourage and reward fast reaction times (Lara-Cabrera, et al., 2013).

The next two challenges of RTS video games that will be discussed are the logical and mathematical challenges followed by exploration challenges. These have been indicated in figure 2.9 that follows.

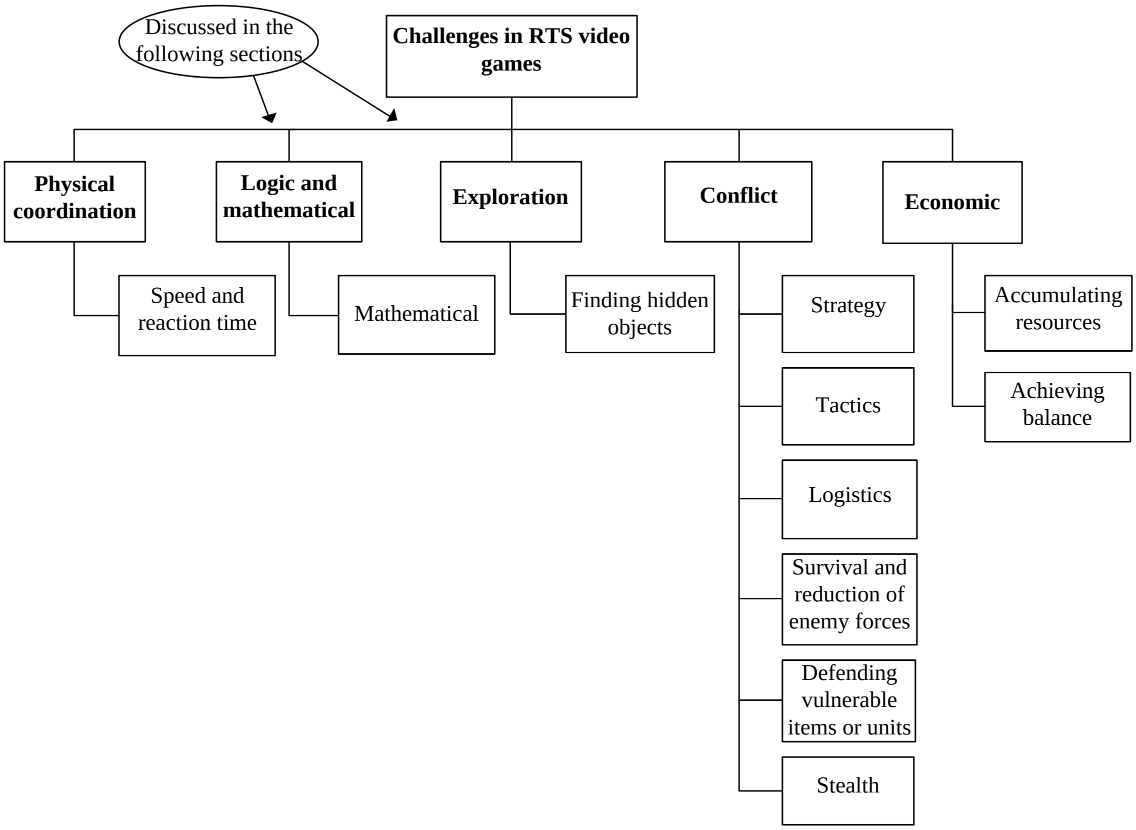


Figure 2.9 - Challenges in RTS video games (logic, mathematical and exploration indicated)

- **Logic and mathematical challenges**

In any turn-based game especially turn-based strategy games, logic provides the basis of strategic thinking (E. Adams, 2009). In games where chance plays a role and when a player does not have reliable data to work with, reasoning is required from probabilities (E. Adams, 2009).

- **Mathematical Challenges**

Video games do not test a player's mathematical skill explicitly but require the player to reason about probability (E. Adams, 2009). Many games include random elements or elements of chance and require the player to make educated guesses using imperfect information (E. Adams, 2009).

RTS video games include implicit mathematical challenges. Skilled players constantly calculate the strength of their armies and their opponents, by assessing the number of military units, the type of military units and currently equipped upgrades and technologies that have been researched (explored in section 2.7.2 of this chapter and appendix D). Quick and accurate estimates of army strengths empower the player to make decisions such as attacking, retreating or consolidating army strength by creating additional military units or researching additional technologies and upgrades.

- **Exploration challenges**

Players enjoy moving into new areas and seeing new things (E. Adams, 2009; Rouse, 2010). This freedom of exploration only comes after completing the necessary exploration challenges presented to the player (E. Adams, 2009).

  - **Finding hidden objects**

Many video games require the player to obtain hidden objects in areas that are difficult to reach which are located in their character's virtual space (E. Adams, 2009). The player must adapt by learning how to navigate in their character's immediate surroundings while keeping an eye out for the object they are looking for (E. Adams, 2009).

While this type of challenge is not explicitly found in RTS video games, finding the enemy is part of a successful strategy. In StarCraft an important element of gameplay is the fog of war (Blizzard Entertainment, 1999).

The fog of war refers to the lack of vision on areas of the map that do not contain a friendly unit. Only the terrain and buildings in their last known state are viewable. Such areas can be updated by sending a friendly unit to scout the area. Keeping information hidden from the opponent whilst gathering intelligence on their activities is a key strategy to winning in StarCraft. Prior knowledge on enemies' movements and army composition allows the player to counter their opponents' actions. It becomes more difficult to develop a winning strategy with no knowledge of opponents' activities.

The next challenge presented in RTS video games that will be examined are conflict challenges and are indicated in figure 2.10 that follows.

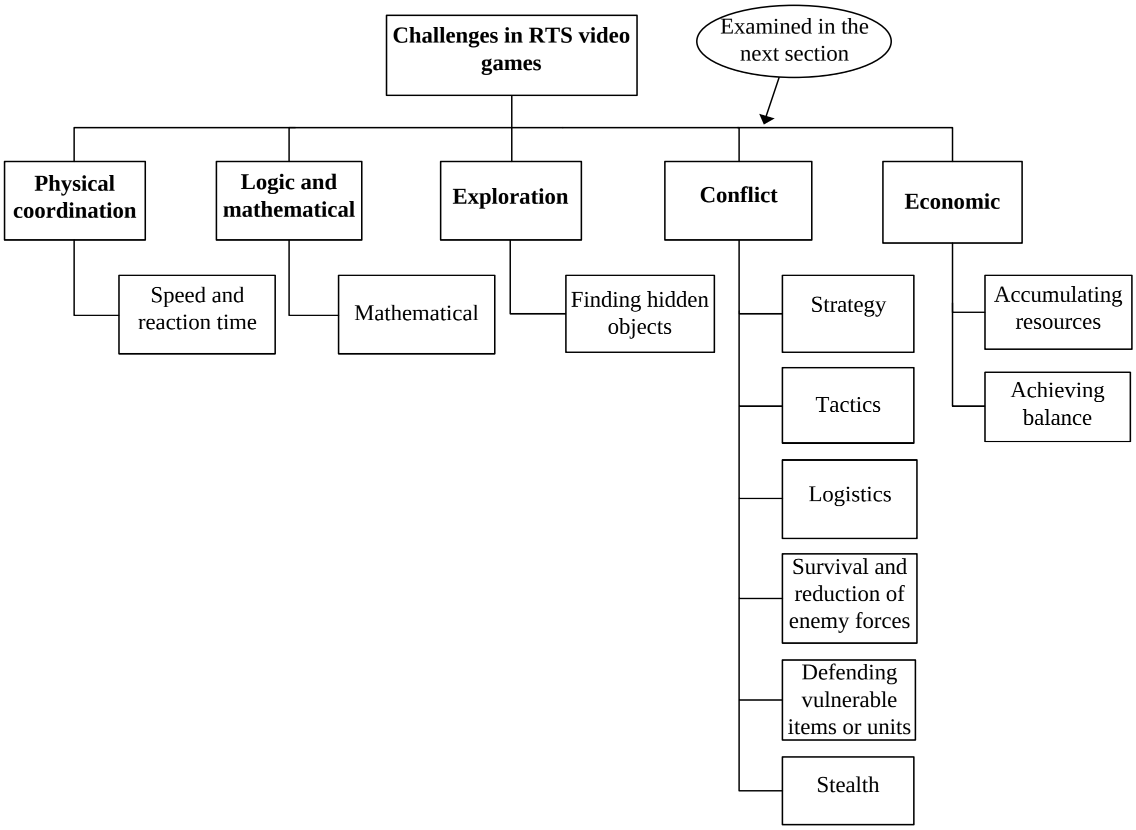


Figure 2.10 - Challenges in RTS video games (conflict indicated)

- **Conflict**

In conflict challenges, a direct opposition of forces occurs (E. Adams, 2009). Video games with conflict challenges are played against enemies who may be human or computer-controlled (E. Adams, 2009). A player must oppose or impede the other player to win even if no combat or violence ensues (E. Adams, 2009). A key strategy to winning conflict challenges is to hinder opponents' actions whilst disrupting their resource supply (E. Adams, 2009).

  - **Strategy**

Effective strategies requires planning, understanding and mitigating one's weaknesses, taking advantage of a situation and anticipating the opponent's moves (E. Adams, 2009). Constant analysis of the game state and devising plans of actions are activities involved in strategizing (E. Adams, 2009). Turn-based video games portray perfect information (a game that contains no hidden information or elements of chance) and players use pure strategy to plan their actions based on estimating future game states (E. Adams, 2009).

In other video games, some information is hidden and elements of chance exist requiring some degree of guessing and probability weighing instead of logic (called applied strategy) (E. Adams, 2009). E. Adams (2009) asserts that RTS video games involve applied strategy. He also claims that some degree of guessing is involved in RTS video games and that the game can be played by players with average logical skills. Furthermore, E. Adams (2009) states that they provide other means of winning besides strategy alone.

While these facts may hold true in many RTS video games they do not apply to StarCraft and StarCraft 2. StarCraft players are only left to guess their opponents' actions if they are unable to scout and gather intelligence on them (a manoeuvre described under exploration challenges and explained further under stealth challenges in this section). Logic and mathematical skills are essential in estimating the outcome of battles through army strength calculations (as described in their respective sections).

Moreover, players implement specific strategies to counter their opponents' actions. For example, the "five pool" is an aggressive strategy implemented by Zerg players against Protoss opponents (the races of StarCraft are described in section 3.9 of chapter three). The goal of this strategy is to overwhelm the Protoss opponent with extremely early Zerglings[2]. Like all strategies, this strategy is not unbeatable and can be thwarted by good micro-management of Protoss Probes (to avoid being killed by the Zerglings) and early construction of a Protoss Gateway to produce Zealots[3] (to kill the Zerglings).

The elements of chance are drastically reduced through the continued analysis and tweaking of the game by Blizzard Entertainment through patch updates. These updates are intended to bring StarCraft to a balanced game state, where no strategies are overpowering or unbeatable.

- **Tactics**

Tactical challenges involve executing a strategy to accomplish the goals of the video game (E. Adams, 2009). Players are compelled to respond to new information, unexpected events and additional conditions (E. Adams, 2009). An overall strategy is needed to win games with strategic challenges, but the tactical challenges entail how the player carries out the strategy to emerge victorious (E. Adams, 2009).

Tactical play is a fundamental aspect of StarCraft. Players take countless tactical actions as they change or adapt their strategies throughout a skirmish based on the state of the game. The tactical actions that players may make in an encounter are too vast to summarize in this dissertation. However, some tactical actions that players will make during a skirmish include: attacking the enemy at strategically advantageous locations or performing hit-and-run tactics.

---

[2] Zerglings are low cost melee units with low health which are effective groups, especially when upgraded with technologies. They are the earliest military units a Zerg player can morph (Blizzard Entertainment, 1999).

[3] The Zealot is the first military unit Protoss players have access to. They are robust units that have large health pools with a strong damage output (Blizzard Entertainment, 1999).

- **Logistics**

Logistical challenges entail the transportation of fresh armies to the field of battle and the support of troops that are currently fighting (E. Adams, 2009). In RTS video games such as StarCraft, players are faced with a decision of constructing their military facilities in varying locations. For example, players may opt to construct these facilities closer to the enemy territory or fields of battle. Although risky, troops would be created closer to the enemy or battlefield enabling them to reach the frontlines sooner.

Additionally, some maps contain impassable terrain. These areas such as islands can only be reached via transporting troops in Terran Dropships, Zerg Overlords or Protoss Shuttles. This presents an additional layer of logistical challenges to the player.

- **Survival and reduction of enemy forces**

The key aspect to achieving victory in video games that present conflict challenges is survival (E. Adams, 2009). The player needs to preserve their lives, units or their chances given to achieve victory (E. Adams, 2009).

In an RTS video game, survival means preserving the lives of as many units as possible whilst weakening and destroying the enemy's units and structures.

- **Defending vulnerable items and units**

Players are often called upon to defend weaker units or structures that are not capable of defending themselves. In StarCraft, players will often strike at their opponents' economy by destroying resource gathering units if left unguarded. These resource gathering units (Terran SCV, Zerg Drone and Protoss Probe) do not possess any powerful self defence mechanisms and are fragile. Thus, players need to provide adequate protection to their mineral lines and resource gathering units to ensure a steady flow of resources.

Transports (as described in the logistical challenges section) also introduce the challenge of defending vulnerable units. Like resource gathering units, they do not possess weaponry and need to be guarded on route to their destinations when carrying passengers. When a transport is destroyed in StarCraft, all its cargo and passengers are lost with it. Hence the protection of these vulnerable units (more so when loaded), is paramount.

Finally, some units are capable of unleashing deadly abilities that can decimate groups of enemies (such as the Protoss High Templar), provide the player's units with additional strength or disable the enemy's units. Their weaknesses lie in their low health pools and inherent lack of self-defence. Keeping these powerful spell-casting units safe and away from danger is pivotal in gaining an advantage over an opponent and destroying their armies.

- **Stealth**

The ability to move and perform actions undetected by the enemy is a valuable skill in conflict challenges and is often required to win in some games such as Splinter Cell where victory can only be achieved by completing missions undetected (E. Adams, 2009; Ubisoft Montreal, 2002).

In StarCraft, moving troops of units across the map unnoticed enables surprise attacks which grant players strategic advantages over their opponents. A player who is able to keep their activities hidden from their opponents would be able to build army compositions that opponents would be unable to defend against or unleash attacks in key or vulnerable areas with devastating effects.

The final challenge that RTS video games present to players are economic challenges. These economic challenges are highlighted in figure 2.11 below and will be reviewed in the next section.

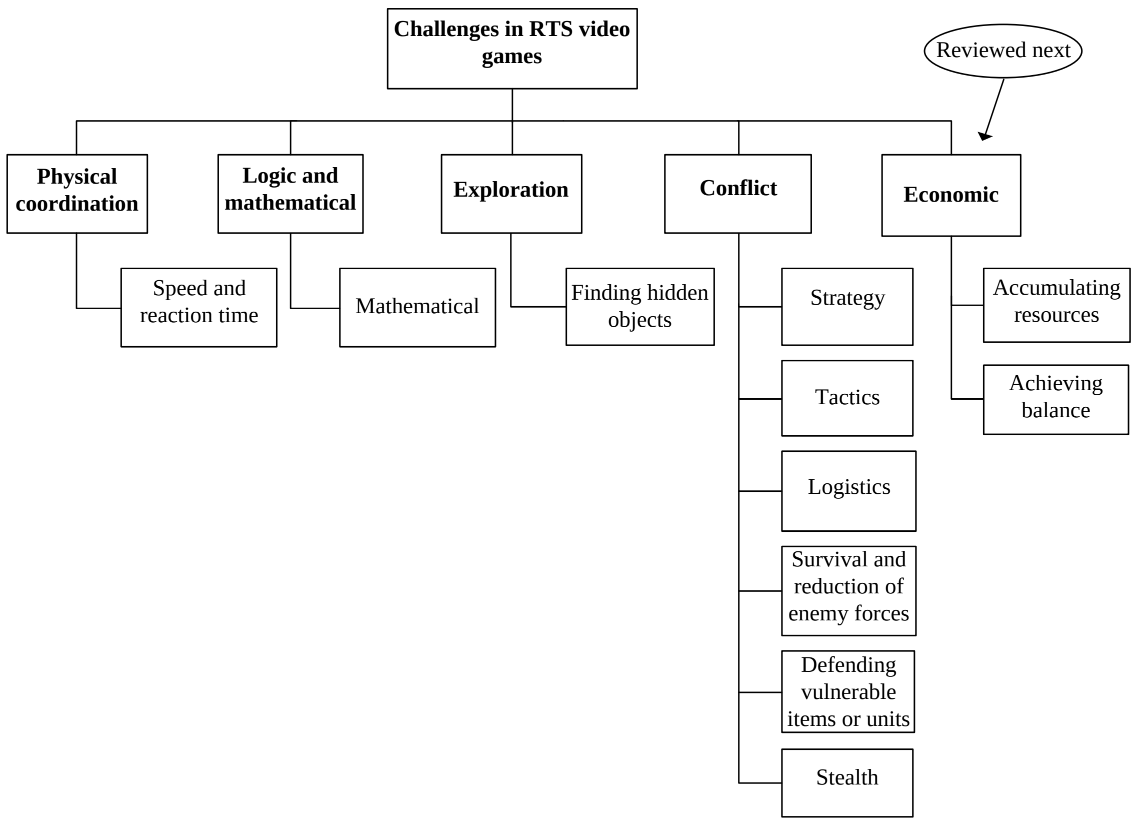


Figure 2.11 - Challenges in RTS video games (economic indicated)

➢ **Economic challenges**

An economic system entails resources being transferred physically or from player to player (E. Adams, 2009). In StarCraft, the currently available resources to spend are minerals (number next to the blue icon in the top right hand corner of the screen) and Vespene Gas (number next to the green icon in the top right hand corner of the screen) (see figure 2.2 in section 2.4.1). The expenditure of these resources needs to be split optimally between research and development, the building of new structures and the creation of military units.

▪ **Accumulating Resources**

The identification of the mechanisms that facilitate wealth creation and using them to a player's advantage is pivotal in economic challenges (E. Adams, 2009). In StarCraft, players are faced with a choice throughout the game to expand and construct outposts in locations that possess richer resource nodes. This is especially dangerous in the early stages of a skirmish where players would have forgone the production of military units to expand. This expansionist strategy leaves outposts (and primary bases in the early stages of a skirmish) vulnerable but can provide a massive economic advantage over an opponent as the game progresses.

Additionally, some units cost more minerals than others to produce whilst others require substantial Vespene Gas investments. Players are required to harvest a sufficient amount of resources from the correct resource nodes to maintain their strategy. Finally, instead of building limited amounts of military units over a period of time, large numbers of resources can be pooled and spent all at once, to produce a sizeable army in a short period of time.

▪ **Achieving balance**

Balancing resource acquisition and expenditure is an important skill to acquire in economic challenges (E. Adams, 2009; Lara-Cabrera, et al., 2013). In StarCraft, players constantly face a choice throughout the early stages of the game. This choice is to spend their available resource to produce units that may gather more resources (to strengthen economy for the long term) or to build military units (for defence or offence in the short term).

Another challenge players' face when building an army is the population limit which limits the size of an army. The maximum number of units that a player can produce is referred to as "control" for the Zerg race, "supply" for the Terran race and "Psy" for the Protoss race. A player may produce new units as long as the cumulative "control cost" (in the case of the Zerg race) of all active units does not exceed the number of available control counters. This number can be increased by constructing select units or structures that increase the number of control counters up to a maximum of two hundred. Each unit consumes a portion of the population limit. Weaker units such as Terran Marines consume one supply whereas more expensive and stronger units such as the Terran Battlecruiser consume six. Players are challenged throughout the game by choosing to spend their available resources on increasing their maximum army size, military units, units that gather resources and upgrades.

As stated at the beginning of this section, the purpose of exploring the challenges in RTS video games (in particular StarCraft) was to highlight the extent of the cognitive load they place on players. The number of challenges that RTS video games present and the activities involved in them reveal that RTS video games (in particular StarCraft) place high cognitive load on players.

Furthermore, the state of RTS video games is continuous and there are no pauses or breaks for players to decide on potential actions to overcome the gameplay challenges. These facts reinforce the notion created by other researchers that RTS video games are an ideal training tool for improving higher level cognitive abilities and performance in tests measuring executive functions (Basak, et al., 2008; Glass, et al., 2013).

Having addressed the first aspect of E. Adams (2009) definition which is "the challenges that a player must face in order to arrive at the object of the game" (E. Adams, 2009, p. 11), the second aspect of gameplay is indicated in figure 2.12 below and will now be discussed as outlined earlier. The second aspect of his definition of gameplay is "the actions that the player is permitted to take to address those challenges" (E. Adams, 2009, p. 11). This second aspect is being discussed to further investigate the nature and extent of task switching that occurs in RTS video games such as StarCraft.

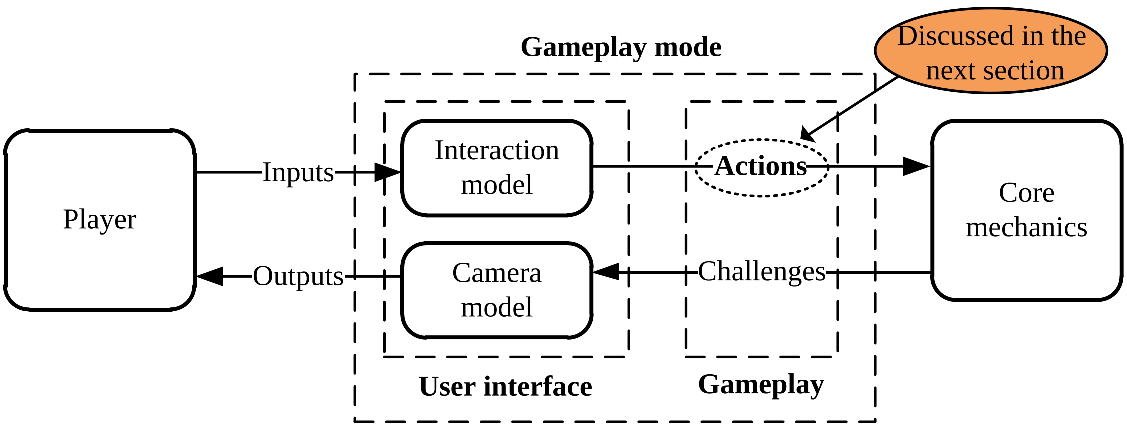


Figure 2.12 - Gameplay mode (actions indicated) (E. Adams, 2009)

2.6.2 Gameplay actions

The second aspect of E. Adams (2009) definition of gameplay states that the actions a player is permitted to take to overcome the challenges form part of gameplay. These actions are a result of some input given by the player to the game via input devices which the user interface interprets. For example, in an RTS video game, selecting a group of military units with the mouse and right clicking on an enemy structure orders those units to attack that structure. The interaction model (discussed in section 3.7.1) that the video game contains for a particular gameplay mode, determines the kinds of actions the player is permitted to perform.

Examples of some actions a player can issue to their units are show in figure 2.13 below which depicts a Terran Ghost in StarCraft. The actions that this unit can perform to overcome challenges are labelled in figure 2.13 below and listed in table 2.2 that follows.

Figure 2.13 - StarCraft unit (Terran Ghost) actions (Blizzard Entertainment, 1999)

Table 2.2 - StarCraft unit (Terran Ghost) actions list

Object	Action
A	Move
B	Stop
C	Attack
D	Patrol
E	Hold position
F	Cloak/de-cloak
G	Lockdown
H	Call in nuclear strike

Figure 2.13 and table 2.2 above, illustrate the potential actions that a player can assign to a particular unit in StarCraft. This unit is one of many that a player will control during a skirmish (see achieving balance in section 2.6.1 of this chapter). This further intensifies the magnitude of task switching that occurs within StarCraft as players' micromanage their forces, where each unit is capable of performing varying actions up to a maximum of nine (explained in section 2.4.1 of this chapter under RTS video games).

The previous sections have addressed the concept of the gameplay (made up of challenges and actions) of StarCraft to establish that the challenges that StarCraft presents impose high cognitive load on players and the potential actions that can be assigned to units proliferates the task switching StarCraft requires.

The next segment of this discussion of the gameplay mode addresses the core mechanics of RTS video games with particular attention to the core mechanics of StarCraft as specified in figure 2.14 below. This analysis is necessary to identify the characteristics of StarCraft's core mechanics that augment the task switching StarCraft demands and the cognitive load they place on players. Furthermore, the rules of StarCraft will be explored in the next section which will further explain how StarCraft works which is central to this study. The next segment begins by defining the concept of the core mechanics of a video game.

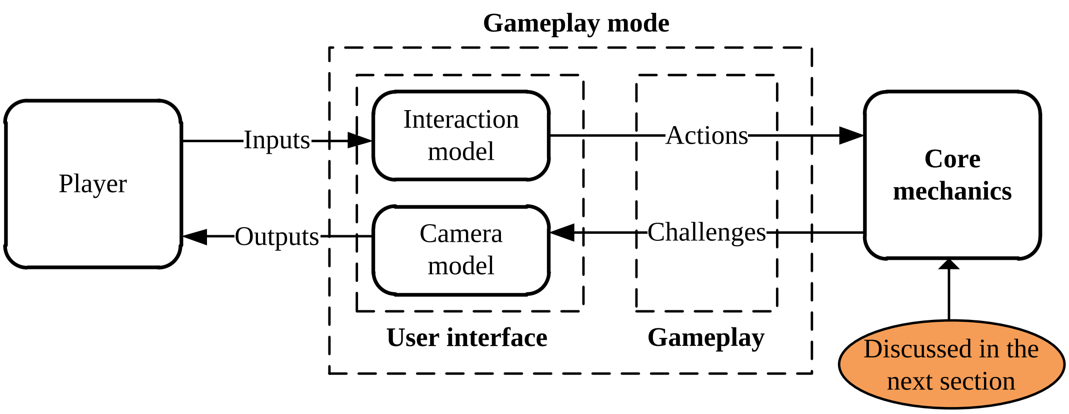


Figure 2.14 - Gameplay mode (user interface indicated) (E. Adams, 2009)

2.7 Core mechanics

Two definitions of core mechanics have been picked out for further explanation. Both Fabricatore (2007) and E. Adams (2009) emphasize the importance of the core mechanics in a video game. E. Adams (2009) declares that the core mechanics are at the heart of any video game whilst Fabricatore (2007) states that the core gameplay activities are the most important in a video game since players use them the most during their experience. Their definitions will be used and explained briefly below.

Fabricatore (2007) states that the core mechanics are, "the set of activities that the player will undertake more frequently during the game experience, and which are indispensable to win the game" (Fabricatore, 2007, p. 12). For example, the core gameplay of Tetris include actions that are aimed at altering the shapes of blocks and fitting them together.

E. Adams (2009) provides an alternate definition declaring that, "the core mechanics consist of the data and the algorithms that precisely define the game's rules and internal operations" (E. Adams, 2009, p. 286). He explains that the core mechanics define the challenges that the game presents to the player and the actions they are permitted to take to overcome them (E. Adams, 2009). They determine the effect of the player's action on the game world, state the conditions for achieving goals and the consequences of succeeding or failing them (E. Adams, 2009). Finally, the core mechanics calculate the extent of actions and send messages back to the user interface instructing it to show the result (E. Adams, 2009). For example in fighting games, holding down a button commands the player's character to execute a slow, strong kick whereas tapping the button results in the character executing a weaker but quicker kick.

The core mechanics that amplifies the cognitive load on players and augment the task switching that StarCraft demands will now be examined. All other mechanics of StarCraft (which includes the numerical attributes) that players must take into consideration at all times during a battle can be viewed in appendix D.

2.7.1 The design of units

Units in RTS video games usually fall into unit types (E. Adams, 2009). Units of each type share attributes and characteristics (E. Adams, 2009). However, some units may possess special abilities that make them unique (E. Adams, 2009). An example of units in StarCraft is the Terran SCV, the Zerg Drone and the Protoss Probe. These three units fall into the small ground unit category. All have the capability of gathering minerals or gas from resource nodes and constructing buildings. A special property of these three units is that Zerg Drones are consumed in the process of constructing buildings. Protoss Probes "warp" buildings into the game world that allows them to perform other tasks whilst the building is being "warped". Terran SCVs follow normal construction behaviour.

- **Special capabilities**

In StarCraft, many units possess special abilities that have an effect on tactics and strategic play. Some abilities influence a unit's attributes. Units that are capable of casting spells in StarCraft have an energy attribute (see appendix D for numerical attributes of units). An example of the special abilities of a unit in StarCraft is illustrated in figure 2.15 that follows. Figure 2.15 depicts a Terran Ghost with special abilities are labelled as F (cloak/de-cloak), G (lockdown) and H (call in nuclear strike) which are listed in table 2.3 thereafter.

Figure 2.15 - StarCraft unit (Terran Ghost) actions (Blizzard Entertainment, 1999)

Table 2.3 - StarCraft unit (Terran Ghost) special capabilities

Object	Action
F	Cloak/de-cloak
G	Lockdown
H	Call in nuclear strike

Selecting a group of Terran Ghosts and issuing a command would cause all of them to perform that action. For example, if the lockdown ability is used on a valid target whilst a group of Ghosts are selected, all Ghosts will use the lockdown ability on the same target. This is inefficient utilization of the ability as all uses of the lockdown ability beyond the first become redundant. Hence, players micro-manage each unit with special abilities to optimally spread their effects amongst many targets. This further intensifies the task switching that StarCraft demands.

- **Unit costs and production rates**

Each unit in StarCraft costs a predefined amount of resources (minerals and Vespene Gas) to produce. The amount of population that unit consumes needs to be available in order to produce that unit. Furthermore, different units require varying amounts of time to build them. For example, Terran Marines have a build time of twenty four seconds whereas large capital ships such as Terran Battlecruisers require one hundred and thirty three seconds to produce. This adds to the strategic challenge that players face in RTS video games as they need to account for unit costs and production times when executing their strategies.

2.7.2 Upgrades and technology trees

Upgrades in StarCraft can enhance units' combat capabilities and can range from increasing their sight range, attack speed, energy, movement speed and grant new abilities.

- **Researching upgrades**

Each upgrade in StarCraft costs a predefined number of resources which takes time to research. Some upgrades can only be researched once their prerequisites have been met. For example researching Zerg melee attacks level two can only be researched once level one has been reached and a Zerg Lair has been constructed. Multiple upgrades exist for each unit giving the player a choice on which upgrade to research first based on their strategy magnifying the complexity of the strategic challenge that players must overcome (E. Adams, 2009).

2.7.3 Logistics

Some aspects of logistics include the management of production, supply, maintenance and distribution (E. Adams, 2009). The logistical challenges associated with the location of military facilities and the challenge of transporting troops over impassable terrain has been discussed in section 2.6.1.

E. Adams (2009) has mentioned another rule of RTS video games related to logistics which is the influence map. The influence map refers to objects that affect the terrain around them (E. Adams, 2009). Two of the three races in StarCraft operate on the concept of the influence map (E. Adams, 2009). For example, the Protoss are required to produce pylons which emit energy around them. Regular buildings may then be "warped in" that are within the emitted energy field. A building without a nearby pylon to support it becomes unpowered and inoperable. Similarly, the Zerg can only construct their buildings on creep (a living substrate) which gradually spreads over a period of time. This is another logistical issue players must consider at all times when playing with the Zerg or Protoss races in StarCraft.

In this section the core mechanics of video games were defined and the rules of StarCraft were explored to explain how StarCraft works. The characteristics of StarCraft's core mechanics that augment the task switching that StarCraft demands and the cognitive load they place on players were also identified. The next section explores the final element of the gameplay mode which is the user interface as indicated in figure 2.16 that follows. First, the user interface of video games will be defined followed by the two elements it encompasses (the interaction and camera model). This has been done to further demonstrate how players interact with StarCraft in addition to the cognitive load and task switching StarCraft demands through its interaction and camera model.

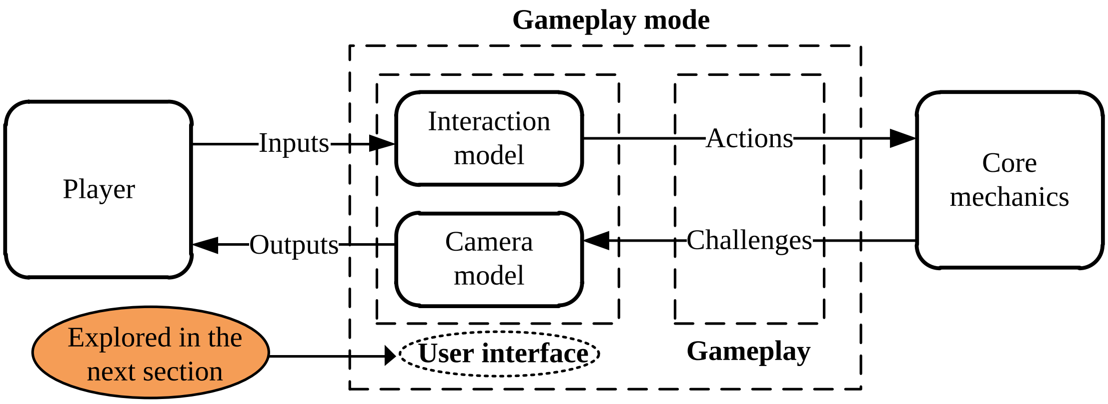


Figure 2.16 - Gameplay model (user interface indicated) (E. Adams, 2009)

2.8 User interface

In computing terms the Graphical User Interface (GUI) is a system used for interacting with a computer through graphical elements (e.g. buttons and icons) and text. User interfaces in video games are responsible for various functions. The interface mediates between the core mechanics and the player (E. Adams, 2009) and determines how players interact with the video game (Brathwaite & Schreiber, 2008; Rouse, 2004). It also takes the challenges generated by the core mechanics and outputs them via the output devices (such as the screen and speakers) (E. Adams, 2009). Furthermore, it receives user input from the hardware (such as button presses, movements and mouse clicks) and translates them into actions within the context of the game (E. Adams, 2009; Kanev & Sugiyama, 1998; Rouse, 2004).

The user interface also depicts the story of the video game, should there be any (E. Adams, 2009). It is also responsible for providing information to the player about the effects of their activities and communicating to players the state of the game world, their avatar or character and units they control (E. Adams, 2009; Poh, 2013; Rouse, 2004). This information is referred to as feedback and the user interface is responsible for how players receive this feedback (E. Adams, 2009; Brathwaite & Schreiber, 2008; Poh, 2013).

In StarCraft, the user interface allows the user to issue commands to one unit or groups of up to twelve units. Furthermore, these groups can be programmed to hotkeys ranging from zero to nine which serve as shortcuts to select those units. E. Adams (2009) includes two elements that form part of video game user interfaces; the interaction model and the camera model. The next section discusses the interaction model that he has described.

2.8.1 Interaction model

The connection between the player's inputs and subsequent actions are dictated by the video game's interaction model. The interaction model determines how players impose their choices in the video game and what they may act on in any given moment (E. Adams, 2009). For example in avatar-based interaction models (which are used in FPS), the player can only influence the game world that surrounds the character.

In RTS video games, an omnipresent interaction model is utilized that grants the player the capability of acting upon any area of the game world in real-time (E. Adams, 2009). As such, players must constantly switch between performing actions on various locations of the game world. This suggests that RTS video games involve more task switching than video games in other genres, further justifying the use of StarCraft in this study as a tool for improving task switching abilities.

To facilitate these actions on various locations of the game world, RTS video games such as StarCraft employ a specific camera model (E. Adams, 2009). The following sub-section briefly describes the camera model.

2.8.2 Camera model

The user interface should display the game world from a point of view that allows the player to take the permitted actions at any given point in time (E. Adams, 2009). Camera models can be static or dynamic (the camera moves in response to event or players' actions) (E. Adams, 2009). First-person, third-person and side scrolling camera models are all examples of various camera models each encompassing its own advantages and disadvantages (E. Adams, 2009; G. King & Krzywinska, 2002).

RTS video games such as StarCraft are played from an aerial perspective and players are obligated to be aware of events that occur within the game world that are not currently visible on screen (refer to figure 2.2 for a graphical representation of the camera model used in StarCraft) (E. Adams, 2009; G. King & Krzywinska, 2002). As mentioned before, this places more cognitive load on players as they make decisions and perform actions across multiple information sources (Glass, et al., 2013).

The gameplay model derived by E. Adams (2009) was utilized to explain the various aspects of video games and StarCraft. Each element of the gameplay model was explored to highlight their implications on the cognitive load StarCraft places on players and the extent of task switching involved in the game. The way in which all the elements of the gameplay mode combine to form a video gaming experience (which falls outside the scope of this study) is explained in appendix C.

The next section of this chapter shifts the attention from the first focus area of this study (RTS video games) to the second focus area: task switching, one of the many executive functions.

Research on the effects of video games on executive functions will first be reviewed followed by a discussion of executive functioning in humans.

2.9 Research on the effects of video games on executive functions

The impact of video games on human cognition and executive functions is an area that has been extensively examined, which is demonstrated in the continuous work by various psychology experts over a period of time (Cain, et al., 2012; Green & Bavelier, 2003, 2006, 2007; Green & Bavelier, 2012; Green, et al., 2012). The effect of video games on executive functions is a broad field that generally looks at the functions listed in table 2.4 below.

Table 2.4 - List of executive functions

Function	Authors
Motor skills	Griffith, et al. (1983) Orosy-Fildes and Allan (1989)
Memory	Ferguson, et al. (2007) Boot, et al. (2008)
Learning	Pillay (2002) Orvis, et al. (2006) Blumberg, et al. (2008) Green and Bavelier (2012)
Problem solving skills	Blumberg, et al. (2008)
Spatial reasoning	Dorval and Pepin (1986) McClurg and Chaillé (1987) Quaiser-Pohl, et al. (2006)
Task switching	Colzato, et al. (2010) Cain, et al. (2012) Green, et al. (2012) Glass, et al. (2013)
Visual attention	Greenfield, et al. (1994) Green and Bavelier (2003) Green and Bavelier (2006) Green and Bavelier (2007)

The debate on video games as a means of improving basic perceptual skills and cognitive abilities has been continuously discussed and examined over time (Boot, et al., 2008; Butler & Dee, 2012; Cain, et al., 2012; Clark, et al., 1987; Colzato, et al., 2010; Frederiksen & White, 1989; Gopher, et al., 1994; Green, et al., 2012; Hart & Battiste, 1992; Karle, et al., 2010). For example, the conclusion of one study that was conducted showed that playing Donkey Kong and Pac Man improved the reaction times of older adults significantly when compared to those who did not play (Clark, et al., 1987). Another video game called Space Fortress was considered to be so successful, that it was incorporated into the training program of the Israeli Air Force (Boot, et al., 2008; Gopher, et al., 1994; Hart & Battiste, 1992).

However, recent studies have shown conflicting results. One such study concluded that students who reported playing higher amounts of video games per week had higher switching costs and took more time to switch between tasks (Butler & Dee, 2012). This study aims to contribute to the debate on the benefit or ill-effects of video games on executive functions.

Having established that video games have been used in research on various executive functions and contrasting results have been found, executive functions will now be explained in detail. As stated earlier, task switching, one of the many aspects of executive functions, forms the second focus area of this study, making the understanding of executive functions essential.

2.10 Executive functions

Many explanations have been offered by various authors that define executive functions in humans. Also termed cognitive control/executive control, one such description of executive functions is, “a product of the co-ordinated operation of various processes to accomplish a particular goal in a flexible manner” (Funahashi, 2001, p. 1). Another explanation of executive functions offered by Cooper-Kahn and Dietzel (2008) is “a set of processes that all have to do with managing oneself and one's resources in order to achieve a goal” (Cooper-Kahn & Dietzel, 2008, para. 4). It is the responsibility of the executive system to facilitate flexible behaviour to achieve a specific goal (R. Elliott, 2003). Thus coordination, control and goal-orientation are fundamental in healthy executive functioning (R. Elliott, 2003).

Whenever an individual thinks, cognitive functions are in control (Kuhns, 2007). They allow humans to focus their resources and perform non-routine complex actions making them essential for achieving flexible behaviour (Cooper-Kahn & Dietzel, 2008; R. Elliott, 2003; Kuhns, 2007). Furthermore, executive functions are essential in enabling an individual to efficiently switch from performing one task to another (Kuhns, 2007).

Authors differ on what functions cognitive control encompasses. Some of these functions that experts have examined are listed in table 2.5 that follows.

Table 2.5 - List of cognitive flexibility functions

Function	Authors
Updating and maintenance of working memory	R. Elliott (2003) Kuhns (2007) Cooper-Kahn and Dietzel (2008)
Problem solving	Kluwe (1982) Zelazo, Carter, Reznick, and Frye (1997) Alexopoulos, Raue, and Areán (2003)
Attention	Naëgelé, Thouvard, Pépin, and Lévy (1995) Lyon and Krasnegor (1996) Kuhns (2007)
Mental flexibility	Naëgelé, et al. (1995) Dubois, Slachevsky, Litvan, and Pillon (2000) Seeley, et al. (2007)
Emotional/mental control	Cooper-Kahn and Dietzel (2008)
Self-monitoring	Cooper-Kahn and Dietzel (2008)
Inhibition	Miyake, et al. (2000) Kuhns (2007) Cooper-Kahn and Dietzel (2008)
Retrieval of information from memory	Lyon and Krasnegor (1996) Kuhns (2007)
Shifting between mental sets or tasks. Also known as task shifting, attention switching or task switching	Miyake, et al. (2000) R. Elliott (2003) Monsell (2003) Kuhns (2007) Cooper-Kahn and Dietzel (2008)

Cognitive flexibility, which inherits some of the executive functions that have been listed above, will now be discussed. The discussion on cognitive flexibility will demonstrate that task switching is also a cognitive flexibility trait.

2.11 Cognitive flexibility

Cognitive flexibility is an important aspect of human cognition that is associated with fluid intelligence and maintenance of a healthy psyche (Colzato, Van Wouwe, Lavender, & Hommel, 2006; Glass, et al., 2013; Moore & Malinowski, 2009).

Authors are also divided on the exact definition of cognitive flexibility and what it entails. Scott (1962) has defined cognitive flexibility as an individual's ability to think about multiple concepts simultaneously. Another description of cognitive flexibility that has been developed is "the ability to assess and adapt on-going psychological operations and to coordinate the allocation of cognitive processes appropriately in dynamic decision making environments" (Glass, et al., 2013, p. 2).

Deak (2003) claims that flexible cognition entails the modification and activation of cognitive processes when a person is faced with changing tasks demands. As the requirements of a task changes (such as its instructions) the cognitive system adjusts by shifting attention, selecting information that will facilitate the correct responses for new tasks and forming plans (Deak, 2003).

Other authors use the terms cognitive flexibility and executive control interchangeably stating that they refer to "those cognitive functions that are concerned with selection, scheduling and coordination of computational processes that are responsible for perception, memory and action" (Crone, Richard Ridderinkhof, Worm, Somsen, & Van Der Molen, 2004, p. 1; E. K. Miller & Cohen, 2001; Norman & Shallice, 1986).

Numerous authors have claimed that one method of determining an individual's level of cognitive flexibility is to measure their task switching ability (Allport, Styles, & Hsieh, 1994; Meiran, Chorev, & Sapir, 2000; Monsell & Driver, 2000). Additionally, Glass, et al. (2013) categorized task switching under cognitive flexibility traits, in their study on RTS video game training and cognitive flexibility.

From the authors' explanations, tests and categorization of tasks that fall under cognitive flexibility, it is safe to suggest that task switching is one aspect of cognitive flexibility, which in turn forms part of executive functions.

Having established that task switching is also an aspect of cognitive flexibility, task switching theory will now be more closely examined. As described throughout this chapter, task switching is one of the two focus areas of this study and therefore requires further investigation.

2.12 Task switching theory

Task switching is concerned with an individual's ability to alternate between performing two or more tasks within a short period of time (Butler & Dee, 2012). Jersild (1927) was one of the first researchers to study task switching. After completing numerous experiments, he developed the first task switching paradigm. In one of his designs, he had respondents switch between two task-sets that were arithmetic in nature. The first task-set contained a single arithmetic task in which the trials were repeated. In the second task-set, trials alternated between two different arithmetic tasks such as addition and subtraction. He then compared the response times from the single arithmetic task-set and the dual arithmetic task-set. The observation made was that response times were higher in the dual task-set than the single task-set (Jersild, 1927). He documented the difference in response times between the two different task-sets and referred to it as the task-switch cost (Jersild, 1927).

The studies discussed in this thesis which have examined the relationship between video game experience or training on task switching performance have drawn their fundamentals and concepts from Jersild's (1927) theory on task switching and switch costs.

Although this switch cost has been replicated multiple times in other studies, the debate continues about the underlying reasons for this switch cost. Several theories have been developed that try to understand the reasons for preparation effects and switching costs in task switching (Badre & Wagner, 2006; Gilbert & Shallice, 2002; Logan & Bundesen, 2003; Schneider & Logan, 2005).

Monsell (2003) is another author who has developed theories that explain the possible reasons for switch costs. Additionally, he has created a summary of all task switching concepts and task switching paradigms that can be used in task switching experiments. This study will adopt the latest developments to the task switching concepts and paradigms created by Monsell (2003). Monsell (2003) is regarded as an expert in the task switching field and his work on this subject has been cited over one thousand times. Furthermore, he has outlined basic task switching concepts and experiment approaches that are suitable for this study.

The following tasks switching concepts related to task switching experiments that Monsell (2003) has described are discussed in table 2.6 below:

Table 2.6 - Task switching concepts

Concept	Explanation
Switch cost	A response usually takes longer on a switch trial than on a non-switch trial (Jersild, 1927; Monsell, 2003). In a task switching experiment, the switch cost is measured as the difference between the reaction time of switch and non-switch trials (Jersild, 1927; Monsell, 2003; Wylie & Allport, 2000). A non-switch trial is a task that a subject performs that is of the same type as the previous task. A switch trial is a task that is of a different type of the previous task which is required to be performed.
Preparation effect	If knowledge is granted to the respondent prior to an upcoming switch trial and if time is given to allow the subject to prepare for it, the average switch cost is reduced (Monsell, 2003).
Residual cost	The preparation effect does not completely eliminate the switch cost (Monsell, 2003). Residual costs of switching tasks remain even when more than five seconds is allowed for preparation (Monsell, 2003).
Mixing costs	Performance improves rapidly after a switch but responses remain slower than when only one task is performed in a block (Monsell, 2003).

In this section basic task switching concepts were described. The next section addresses the various aspects of task switching experiments. These aspects are utilized in this study's tests on task switching and thus require further elaboration.

2.12.1 Aspects of task switching experiments

A method that is used to understand control processes is to understand how a task is completed successfully. Allport, Styles and Hsieh (1994) and Rogers and Monsell (1995) have proposed that the presenting of a stimulus, a response set, and other information are required to complete a task successfully. All of a task's components are referred to as a task-set (Rogers & Monsell, 1995).

Before conducting a task switching experiment, respondents need to undergo pre-training on two or more tasks which they are made aware of by a set of stimuli (Monsell, 2003). Each task requires the respondent to give attention to, classify or compute an element or attribute of the stimulus (Monsell, 2003). For example, a person may need to identify if a number is odd or even or greater or less than five. The task can be successfully completed after receiving an internal or external cue that is offered (Kuhns, 2007; Monsell, 2003). Butler and Dee (2012) define the cue as an aspect of the stimulus that gives an indication of the correct response. In figure 2.17 below, an example of a cue and stimulus where a respondent identifies if a number is odd or even or higher or lower than five is illustrated.

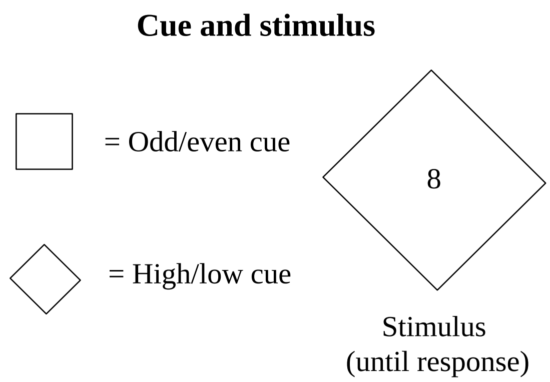


Figure 2.17 - Cue and stimulus example

In this example, the stimulus is the number presented to the subject within the shape. The shape is the task cue which in this example is presented with the stimulus. If the shape is a square the respondent should identify if the number is odd or even. If the shape is a diamond, the respondent should identify if the number is higher or lower than five. These stimuli are presented to the subject in a series of trials.

Tasks will change in a predictable or unpredictable manner with varying amounts of time to prepare for task switches based on the task switching paradigm used in the experiment. Subjects' performance on trials with task switches reflects the switch cost and its extra processing demands. (Monsell, 2003).

Figure 2.18 that follows presents an example of a predictable task sequence. The cues (shapes) that indicate which part of the stimulus to identify are the same as those illustrated in figure 2.17.

Predictable task sequence

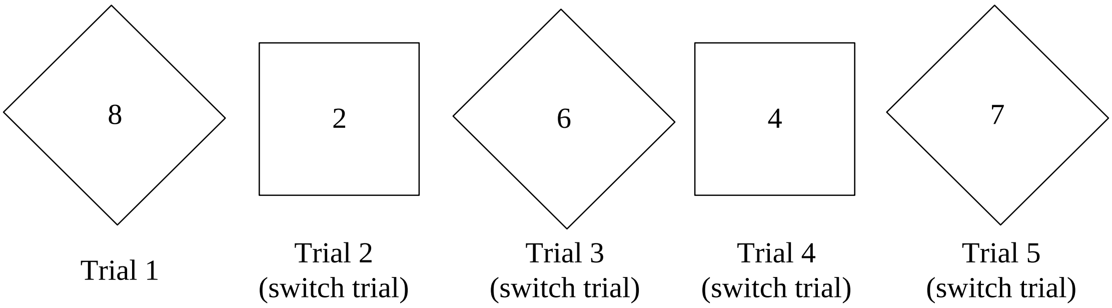


Figure 2.18 - Predictable task sequence example

In this example the subject identifies whether a number is odd or even every alternate trial. Every other trial, the number is judged to be higher or lower than five. This reflects a predictable task sequence. In figure 2.19 below, an unpredictable task sequence is portrayed where the tasks presented in each trial follow no pattern or pre-defined sequence.

Unpredictable task sequence

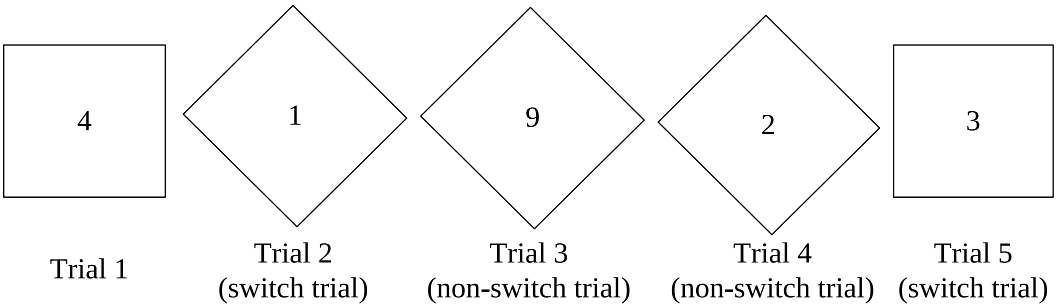


Figure 2.19 - Unpredictable task sequence example

Various paradigms have been created that vary the times at which trials present different tasks. The use of a task-switching paradigm assists in investigating task switching performance (Kuhns, 2007). These paradigms allow for the observation of behavioural and neurological measures (Kuhns, 2007). The next section describes these paradigms and how they work. Comprehending the various paradigms is essential as they are used in every task switching test measure (the task switching paradigm utilized in this study's task switching test is described in section 3.8.3 of chapter three).

2.12.2 Task switching paradigms

Several methods have been created that instruct the subject which task to perform on each trial during a task switching experiment (Monsell, 2003). Jersild's (1927) method is sometimes used whereby blocks of trials are presented where subjects rapidly alternate between performing two tasks and are compared to blocks of trials in which one task is repeated. However, this comparative method combines mixing costs and switch costs (Monsell, 2003). Furthermore, an imposition is created on subjects' working memory load through the alternation blocks of this design which may require greater effort and promote the effects of arousal (Monsell, 2003).

Other task switching paradigms have been created that address the problems in Jersild's (1927) method. These paradigms are listed and explained in table 2.7 below.

Table 2.7 - List of task switching paradigms

Task Switching Paradigm	Purpose	Additional information
Alternating-runs (Rogers & Monsell, 1995).	Task alternates every n trials. N remains predictable throughout the block. This paradigm facilitates the comparison of task-repeat trials to task-switch trials within a block (Monsell, 2003).	In these paradigms the response-stimulus interval can be varied allowing various amounts of preparation times (Monsell, 2003).
Pre-specified task sequence (Allport, et al., 1994; Mayr & Keele, 2000).	Short sequences of trials. E.g. odd/even, high/low, odd/even (Monsell, 2003).[4]	
Task-cueing (Meiran, 1996; Sudevan & Taylor, 1987).	The sequence of tasks is unpredictable and the task cue can be presented before or with the stimulus (Monsell, 2003).	This paradigm allows the cue-stimulus time to be altered facilitating active preparation and the response-cue time allowing for passive dissipation (Monsell, 2003).
Intermittent-instruction (Allport & Wylie, 2000; Gopher, Armony, & Greenshpan, 2000)	Series of trials are regularly interrupted with instructions that specify which task to perform on the trials following the instruction (Gopher, et al., 2000).	A restart cost is incurred following the interruption of trials by the instruction even when it directs the subject to continue performing the same task. However, this cost is larger when the task changes following the instruction. The difference in these two restart costs reflects the switch cost (Allport & Wylie, 2000).

In this section task switching theory was described in detail. The next section revisits the research surrounding the effects of video games on cognitive flexibility. The studies explored in the next section have been divided into two sections.

The first section considers those studies that use video games as an intervention tool and measure their effect on cognitive flexibility through longitudinal research designs. The second

[4] Refer to figure 2.18 in this section for a graphical representation.

section addresses those studies in the literature, which employed cross-sectional designs. These studies identified VGPs and assessed their performances in executive control tasks. Their performances were compared to nVGPs to infer differences between VGPs and nVGPs. The studies that will be discussed are grouped and listed in table 2.8 below. This grouping style has been utilized to delineate their overlaying methodologies and key findings that are relevant to this study.

Table 2.8 - List of other studies

Video game training studies	Non-training video game studies
Boot, et al. (2008)	Colzato, et al. (2010)
Basak, et al. (2008)	Cain, et al. (2012)
Green, et al. (2012)	Butler and Dee (2012)
Glass, et al. (2013)	

2.13 Video game training and task switching studies

The following studies use video games as an intervention mechanism to train respondents and measure their effect on task switching performance.

2.13.1 Boot, Kramer, Simons, Fabiani, & Gratton (2008)

The purpose of a study conducted by Boot, et al. (2008) was to determine if the benefits of video games are restricted to visual and attentional tasks, or if the improvements are broader and extend to other executive control functions. To investigate this, they assessed the effects of video game playing on numerous executive control, reasoning and memory tasks.

They established two groups in their sample; namely a longitudinal group and a cross-sectional group. The cross-sectional group consisted of expert gamers (group X) and novice gamers (group Y). Both group X and Y did not undergo any form of video game training and simply completed all cognitive tests.

The longitudinal group consisted of nVGPs who were primarily female. This group was divided into four subgroups. The video games that these subgroups were made to play are listed in table 2.9 below. These groups completed fifteen training sessions and played these video games for a total of twenty one and a half hours.

Table 2.9 - Video games used by Boot, et al. (2008)

Group	Game	Genre
A (Control group)	No video game practice	N/A
B	Medal of Honor: Allied Assault (MoH)[5]	FPS
C	Tetris	Puzzle
D	Rise of Nations (RoN)[6]	RTS

[5] MoH is a World War II based FPS video game developed by 2015 Inc. (2015 Inc, 2002).

Before assessing the effects of video game training on their tests on executive control, the authors examined if players improved in their respective video game with practice over time. Subjects in groups B, C and D significantly improved their performances in the video games. Furthermore, almost all participants who trained in RoN, achieved victory in the first scenario that was replayed at the end of the training schedule. With practice, participants who played RoN were able to build larger, more advanced societies in less time, and also achieve victory more often (Boot, et al., 2008).

The cognitive tests on executive control and reasoning were completed three times by participants in the longitudinal groups (groups A, B, C and D): before video game training, after ten hours of practice and after twenty-one hours of video game practice by group B, C and D in their study. Additionally their tests included a task switching test, which required participants to judge whether a number (from one to nine) was odd or even or judge if it was low or high (greater or less than five).

The measure used to determine task switching ability was the switch cost. Switch costs were calculated by subtracting the response times of switch trials from the response times of non-switch trials. Boot, et al. (2008) predicted that switch costs would decrease more for participants who played games that required more task switching than others and for participants with no video game experience in the longitudinal groups (group B, C or D). Furthermore, expert VGPs (group X) were expected to have smaller switch costs than nVGPs (group Y).

The results of the task switching tests depicted expert VGPs (group X) displaying lower switch costs than that of nVGPs (group Y) but primarily on the easier task high/low task (where participants had to identify if a number is greater or less than five). Within the longitudinal groups, participants switch costs decreased as they repeated the task switching tests. However, there were no significant switch cost differences between sub-groups A, B, C and D. From this Boot, et al. (2008) concluded that there is no evidence to suggest that video game practice has an effect on an individual's ability to switch between two different tasks.

2.13.2 Basak, Boot, Voss, & Kramer (2008)

The aim of a similar study conducted by Basak, et al. (2008) was to determine if training in a RTS video game would transfer to executive control and memory processes of aging adults. They examined if RoN would improve participants performance in executive control tasks, one of which was task switching. They predicted that RoN would not improve basic visuospatial

---

[6] RoN is a RTS video game developed by Big Huge Games that combines the speed of real-time gaming and complexity of turn-based strategy games (Basak, et al., 2008; Big Huge Games, 2003).

attentional abilities such as focused and selective attention as these cognitive controls are emphasized more in FPS video games than RTS video games.

Forty participants were recruited and split into two groups (A and B). Twenty random participants who were assigned to group A, underwent training in RoN. Members of group A trained for a total of twenty three and half hours. Members of group B formed a no-contact no-training control group.

Game performance was also measured and in the same way as the study conducted by Boot, et al. (2008). Players also replayed the first scenario at the end of the training schedule in this study. The analysis of the game performance revealed that participants reduced the time it took to complete the first scenario and increased their score related to building wonders[7].

Players also increased their score related to player speed. Player speed in RoN is calculated by the number of times a player clicked the mouse or used a hotkey (keyboard shortcut) during a skirmish (Basak, et al., 2008). The drawbacks of using player speed in game performance analysis are discussed in more detail in section 3.9.2 of the research methodology chapter.

The task switching test utilized in the study by Boot, et al. (2008) was also utilized in the study by Basak, et al. (2008). This test was administered three times to participants: at the beginning, halfway and at the end of the study. The difference in the results (switch cost, non-switch reaction times and accuracy) of the task switching tests between the first and second testing sessions were not found to be statistically significant. However, a statistically significant difference was found between the results of the second and third training sessions. Although non-switch reaction times did not decrease with repeated testing and accuracy increased only marginally, group A demonstrated a larger decrease in switch costs with repeated testing than group B. Therefore, they concluded that video game training had a beneficial effect on task switching ability (Basak, et al., 2008).

2.13.3 Green, Sugarman, Medford, Klobusicky, & Bavelier (2012)

The goal of a study by Green, et al. (2012) was to examine the extent to which action based video games modify task switching ability. To accomplish this, they conducted four distinct experiments.

[7] Wonders in RoN are structures that cost a substantial amount of resources to construct and provide strategic advantages (Big Huge Games, 2003). They award additional points to a player's final score and in some scenarios and are required to be constructed or taken over (from enemies) in some scenarios to win (Big Huge Games, 2003).

- **Experiment One**

In the first experiment, they sought to identify whether the reduced task switching cost of action based video game players found in other studies, is related to an enhanced ability to map and re-map responses that utilize button presses (which is a common occurrence in action based games) or if this skill applies to other general responses such as vocal responses.

In this experiment, eighteen male participants were recruited and formed one of two groups. Group A, Action Video Game Players (AVGPs) and group B, Non-Action Video Game Players (nAVGPs) consisted of eight and ten members respectively. No females formed part of this experiment due to the scarcity of females with adequate video game experience.

The task switching test measure used in this study required participants to identify the shape or colour of an object. Subjects completed four blocks of trials in their test on task switching. Two blocks of trials entailed keyboard responses for each task whilst the other two necessitated participants to make their response verbally through a microphone.

The results depicted reduced switch costs of group A (AVGPs) over group B (nAVGPs). Furthermore, these reduced switch costs were not only found in the button pressing response mode but also in the vocal response mode which do not usually form part of action based video game activity.

- **Experiment Two**

The aim of the second experiment was to determine if the benefits AVGPs demonstrated over nAVGPs in experiment one, was similar in magnitude in a task that required the use of more cognitive abilities. In this experiment the instructions were altered to encourage accuracy over speed of responses since emphasis on speed favoured AVGPs over nAVGPs. Two groups were formed for this second experiment. Group A (AVGPs) and B (nAVGPs) comprised of fourteen male participants each. Females were also excluded from participating in this experiment because of the scarcity of females with sufficient action video game experience (Green, et al., 2012). Furthermore, all participants who were recruited in this second experiment did not participate in experiment one.

The task switching test was altered to be more cognitive in nature by making participants identify if a number was odd or even or if it was greater or less than five (Green, et al., 2012). In this second task switching test measure, responses were restricted to keyboard only. All other variables in the test were kept the same as the first experiment. This test was completed in conjunction with the task switching test described in their first experiment (a more perceptual task). Additionally, a distracting task which lasted approximately thirty minutes was presented between blocks to prevent carry-over effects between tasks.

From the results of this experiment the authors noted that the size of the switch cost reduction was equal for both the perceptual task from experiment one and the more cognitive task in experiment two. The two groups in experiment two showed greater accuracy in the tests than the groups in experiment one but this result was biased due to the change in instruction. Nevertheless, they concluded that the switch cost advantage observed in experiment one was not due to speed-emphasis.

The details and results of their third experiment are not closely related to this study and have been excluded. However, their fourth experiment which is relevant to this study will now be detailed.

- **Experiment Four**

In an effort to maximize the potential of finding a significant training effect on task switching ability, they performed a modified version of the study conducted by Boot, et al. (2008). Their RTS video game training schedule was adjusted to be significantly longer than all other studies found and had subjects in this experiment undergo video game training for a total of fifty hours. Their tests on executive control were also limited to pre and post-training only. Their reasoning behind this decision was that repeated testing on the same task increases the risk of task-specific learning (Green, et al., 2012). Task-specific learning implies that a person improves in a task switching test with repeated testing, which can quickly make a particular test battery an inaccurate measure of task switching ability.

All subjects in the final experiment were nVGPS who reported no prior video game experience. Two groups were formed in this training experiment. Group A which consisted of nineteen members were instructed to play fast-paced action based video games such as Unreal Tournament 2004 (UT 2004) (Epic Games, et al., 2004)[8] and Call of Duty 2 (CoD 2) (Infinity Ward, 2005)[9]. Group B comprised seventeen members who played slower paced games which the authors defined as strategy games such as The Sims 2 (Maxis, 2004)[10]. However, not all strategy games are slow-paced as discussed in section 2.4.1 of this chapter. Furthermore, the video game taxonomy of this study categorizes video games such as The Sims 2 (Maxis, 2004) as a Life Simulation video game rather than strategy video game.

---

[8] Unreal Tournament 2004 is a futuristic FPS video game developed by Epic Games and Digital Extremes (Epic Games, et al., 2004).
[9] Call of Duty 2 is a FPS video game developed by Infinity Ward and is the second instalment in the Call of Duty series (Infinity Ward, 2005).
[10] The Sims 2 is a Life Simulation video game developed by Maxis (Maxis, 2004).

The task switching tests in this final experiment that were administered were the same as the first experiment with responses being limited to the keyboard. The post-training tests were conducted a few days after video game training was completed.

Their findings showed that both groups reduced their switch costs after fifty hours of video game training. However, group A demonstrated a greater reduction in switch costs than group B. However, when the switch costs were corrected for baseline reaction times, the change in switching costs between the two groups was found to be only marginally significant. Baseline reaction times will now be examined to give the reader a better understanding of this concept.

As mentioned in the task switching theory section of this chapter, the switch cost is calculated by the difference of the reaction times in switch and non-switch trials. One would expect smaller switch costs in people who depict fast reaction times as was the case with AVGPs in experiment four (Green, et al., 2012). To tackle this problem, switch costs should be analysed as a percentage increase from switch trials to non-switch trials (Green, et al., 2012). This percentage results in a proportional switch cost (Green, et al., 2012).

Green, et al. (2012) elaborate on this marginally significant occurrence (after correcting for baseline reaction times) by suggesting that a portion of the reduced switching costs is a result of faster reaction times. When reaction times are accounted for the effect remains but it is much smaller.

As a final note in this experiment the authors hypothesize a combination of factors that could have diminished possible effects of the training study. The first factor was that the same task-switching paradigm was used pre and post-training which may have resulted in task-specific learning (Green, et al., 2012). They suggest that different task switching paradigms be used pre and post-training.

The second factor was control-based games also improved task switching performance which reduced the difference between the two groups (Green, et al., 2012). Their final point was that although fifty hours of video game training improved reaction times it was insufficient to increase task switching ability to those of expert VGPs (Green, et al., 2012).

2.13.4 Glass, Maddox, & Love (2013)

A recent study conducted by Glass, et al. (2013) sought to ascertain if video game training could alter cognitive flexibility. This study utilized StarCraft (Blizzard Entertainment, 1999) and The Sims (Maxis, 2004) to train three distinct groups. Additionally, Glass, et al. (2013) modified some of the video games to encourage fast thinking, a distinct variation from the other training studies that were conducted. The gameplay of the RTS video game (StarCraft) was altered by disabling the visual alerts on the mini-map and the game's audio. This compels players to rely on memory to determine events that occurred on areas of the map that were not currently visible on screen.

Furthermore, a half-map version and full-map version of StarCraft were designed. The full-map version promoted more task switching and coordination of cognitive resources than the half-map version (Glass, et al., 2013). The half-map version that was designed maintained the difficultly of the full-map version but did not emphasize maintaining as much awareness and task switching as the full-map version (Glass, et al., 2013) .

Participants in this study (primarily female) were nVGPs and joined one of three groups. The first group (Sims) formed a control group and played The Sims 2 (Maxis, 2004) , the second (SC-1) played the half-map version of StarCraft and the third (SC-2) (twenty participants) played the full-map version of StarCraft. These games were played for a total practice time of forty hours.

The alteration of the StarCraft gameplay facilitated game performance analysis in several ways. Several text files were generated from each scenario participants played, recording difficulty (which they defined as the amount of resources made available to the opponent), the number of key presses during the game (player speed or action per minute), the winner and the cumulative resources collected (Glass, et al., 2013).

Furthermore game state features for each scenario that a participant played was recorded (Glass, et al., 2013). These game state features included over fifty pieces of data that were analysed. Some of the data that were constantly being recorded every two hundred and fifty milliseconds included: if every unit a player was currently controlling was being attacked, patrolling/not patrolling, idle/not idle and proportion of health remaining amongst a myriad of other aspects (Glass, 2013).

This data facilitated advanced analysis, enabling the authors to construct a selection/feature analysis. This model empowered the authors to pinpoint which features in the near past drove user actions in the present. Furthermore, a Bayesian model was implemented to determine the number of features a player interacted with. The results depicted that participants in the SC-2 group utilized more game state features than those in the SC-1 group. Glass, et al. (2013) claimed that this supports the argument that interaction with more information sources in StarCraft can result in cognitive flexibility enhancements.

For the task switching test battery, each subject undertook a pre-test battery which presented various cognitive tests. After completing the video game training schedules, subjects performed the same cognitive tests in the post-test battery.

The authors combined the accuracy and response time measures of the cognitive tests using diffusion modelling to arrive at a single measure for task switching performance. For each test, the performance change was measured as the difference between the pre and post-training scores.

The results and statistical analysis revealed that only subjects belonging to the SC-2 training group depicted cognitive flexibility enhancements. From these findings, the authors concluded that training in a RTS video game which promotes rapid assessment and coordination across multiple information sources can alter performance on many cognitive tests making cognitive flexibility a trainable skill (Glass, et al., 2013).

The previous section has addressed the studies found in the literature which utilized video games as an intervention mechanism to train respondents and measured their effect on task switching performance The next section will examine the outcomes of the cross-sectional studies that have examined the effect of video games on executive control.

2.14 Non-training video game and task switching studies

The following studies followed cross-sectional designs and did not train groups with video games. Instead they identified VGPs and compared their cognitive abilities to nVGPs.

2.14.1 Colzato, van Leeuwen, van den Wildenberg, & Hommel (2010)

A study conducted by Colzato, et al. (2010) sought to test the hypothesis that video game experience enhances cognitive flexibility. To do this they identified two groups of individuals. Group A consisted of seventeen members who reported having video game experience particularly in FPS games. Group B also comprised seventeen members who were nVGPS.

Their test on task switching ability assessed the participants' ability to identify geometric figures (squares and rectangles). Inner or outer shapes were identified based on a local or global cue presented. All responses were made via the keyboard only. Furthermore, subjects also completed a thirty minute reasoning-based intelligence test which revealed their IQ scores before undertaking the task switching test.

For their statistical analysis mean reaction times were calculated and analysed. Their findings depicted VGPs demonstrating smaller switch costs than nVGPS. They also ruled out the factors of age and IQ contributing to this occurrence as no statistically significant differences were found between the two groups. VGPs also demonstrated faster reaction times than nVGPs but tended to be less accurate. However, this result lacked statistical backing.

The authors offered two explanations for VGPs superior task switching abilities. The first being that video game experience affects residual switch costs (Colzato, et al., 2010). The authors speculated that VGPs are more efficient in selectively activating and updating task-sets than nVGPs (Colzato, et al., 2010). Their second alternative explanation is VGPs are constantly accused by the media of being anti-social and aggressive (Colzato, et al., 2010). This may have resulted in VGPs being more intrinsically motivated to accomplish the task than nVGPs (Colzato, et al., 2010). From the results of the task switching tests and discussion, the authors concluded that experience in FPS games enhances cognitive flexibility (Colzato, et al., 2010).

2.14.2 Cain, Landau, & Shimamura (2012)

One of the purposes of another study conducted by Cain, et al. (2012) was to investigate task switching performance of VGPs and nVGPs using an alternative task switching paradigm to the studies discussed thus far. Their task switching test had no pre-cues, followed an unpredictable task sequence and included longer inter-trial intervals (the time period between one trial and the next).

Forty four subjects were recruited and divided into two groups. Group A (VGPs) consisted of twenty three participants. All members of group A were male. Group B (nVGPs) comprised twenty one members which included a mix of males and females.

According to Cain, et al. (2012), video games present multitudes of irrelevant and unnecessary visual information and experience in video games may result in improved distractor filtering. To test task switching performance and distractor filtering they used a flanker task. This flanker task involved the presentation of three arrows adjacent to each other. Subjects were required to identify via the keyboard, the direction of the centre arrow whilst ignoring the other arrows on screen. The cue signalled to participants whether to identify the current or opposite direction of the centre arrow.

Like all the previous studies mentioned thus far, mean reaction times were measured. From their analysis, the authors concluded that VGPs demonstrated improved task switching performance in their task switching paradigm which contained long inter-trial intervals. Additionally, they concluded that VGPs could switch tasks more flexibility than nVGPs.

A possible reason for this phenomenon is that given limited physical inputs, VGPs can assign new meanings to buttons with changing modes and scenarios within a video game (Cain, et al., 2012). With regards to distractor filtering, no difference was found between the two groups. From this, the authors suggest that video game experience does not improve visual information filtering (Cain, et al., 2012).

2.14.3 Butler and Dee (2012)

The final study that will be discussed which was conducted by Butler and Dee (2012) sought to examine whether students' video gaming habits and multitasking behaviour affected their task switching abilities.

Twenty eight students (male and female) were recruited for this study. Butler and Dee (2012) employed the Wisconsin Card Sorting Test (WCST) to measure task switching ability. This test required subjects to view a stimulus on a card that contained several attributes such as shape and colour. The subject selected a response card that matched an attribute on the card based on the instruction.

Following the WCST, participants completed a survey which gathered data regarding their multitasking behaviours and technology habits in addition to their weekly video game usage. They were also asked to indicate the time period in which they felt was optimal for studying. Task switching behaviours whilst studying were also described by each subject,

Thirteen participants also completed an activity log. This activity log entailed a record of their activities in half-hour time slots for a period of three weekdays. When multitasking, tasks were recorded as either primary or secondary activities. Finally, the authors interviewed three participants (two with relatively low switching costs and one with relatively high switching costs), asking them about their perceived skill at switching between tasks and their study habits.

The results from the WCST, surveys and questionnaires suggested that students who reported higher amounts video game usage also had higher switch costs. The authors hypothesize a possible reason for this occurrence, suggesting that VGPs have decreased oxygen supply to specific areas of the brain that are responsible for task switching and other executive functions, a finding doctors have demonstrated before (Butler & Dee, 2012; Matsuda & Hiraki, 2006; Meyer, et al., 1997).

The previous section has examined the current state of the literature and signalled the underlying methodologies of these studies. The next section motivates the need for this study by identifying a gap that exists in the literature and how this study intends to fill that gap and contribute to the body of knowledge surrounding the effects of video games on executive functions.

2.15 Situating this study

This study aims to contribute to the constant debate and research that is on-going surrounding the issue of video game usage and cognitive flexibility. Table 2.10 below and figure 2.20 that follows provides a summary of the areas that the longitudinal studies in the literature have focused on and the video games they have utilized. Additionally, the position of this study in the context of the literature is indicated in table 2.10 below and figure 2.20 thereafter.

Table 2.10 - State of the video game training literature

Study	Population Trained	Video Games Used	Outcome
Boot, et al. (2008)	nVGPs	MoH Tetris RoN	No evidence that suggests video game practice improves task switching performance (Boot, et al., 2008)
Basak, et al. (2008)	nVGPs	RoN	Video game training has a beneficial effect on task switching ability (Basak, et al., 2008).
Green, et al. (2012) (Experiment four)	nVGPs	UT 2004 CoD 2 The Sims 2	Marginally significant positive effect on task switching performance (Green, et al., 2012).
Glass, et al. (2013)	nVGPs	StarCraft	RTS video game settings that promote rapid assessment and coordination across multiple sources of information enhances cognitive flexibility (Glass, et al., 2013).
This study	**Non-playing RTS VGPs**	StarCraft	Revealed in chapter four.

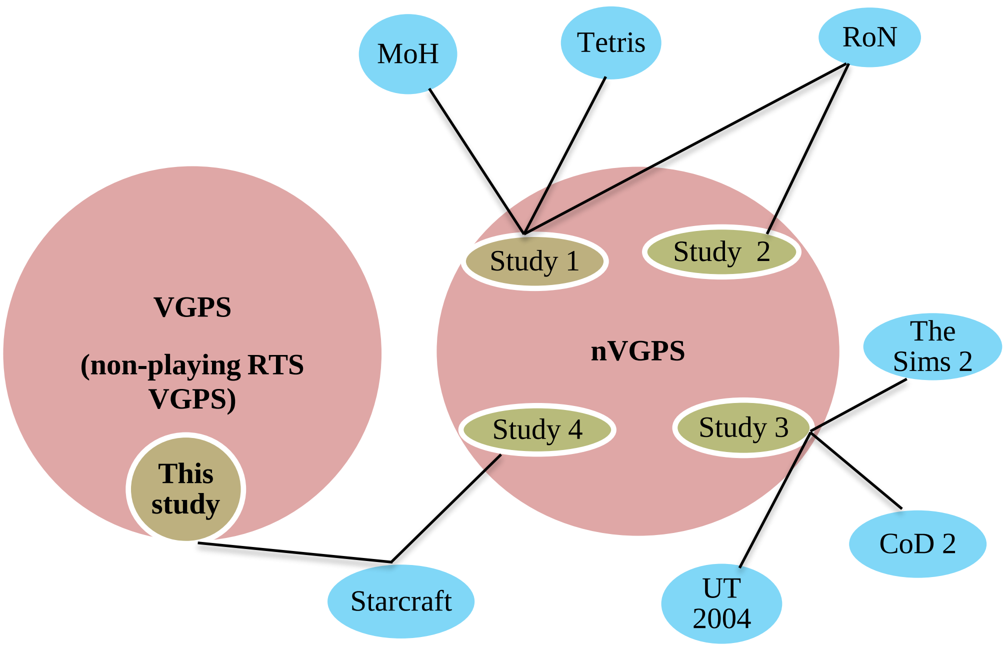


Figure 2.20 - Graphical representation of the video game training literature

One area that authors have suggested for future research which has not been examined extensively, is the effect of specific video game genres on executive functions (Boot, et al., 2008). In RTS video games such as StarCraft, superior task switching skills reward players who constantly switch between performing various tasks and achieving several goals simultaneously such as harvesting resources, researching new technologies, protecting their assets from enemy assaults and managing military units to destroy their enemies (Basak, et al., 2008; Boot, et al., 2008).

These activities which involve task switching on a high scale are performed to meet the complex demands of RTS video games (particularly StarCraft) that constantly change and overcome the various gameplay challenges it presents that have been discussed (Basak, et al., 2008; Boot, et al., 2008). This rapid task switching that takes place across numerous information sources at a high workload make RTS video games an ideal training tool for improving higher level cognitive abilities (Glass, et al., 2013). Therefore, it is acceptable to assume that RTS video games will improve performance in tests that measure cognitive flexibility, particularly task switching (Basak, et al., 2008).

The studies by Boot, et al. (2008), Basak, et al. (2008) and Glass, et al. (2013) have tested the effects of the RTS video game genre on nVGPs. However, no studies have been found that examine the training effect of a specific video game genre on current VGPs cognitive flexibility (as illustrated in figure 2.20 and table 2.10). Thus, this study will look at non-playing RTS VGPs (current VGPs who don’t play RTS video games) and attempt to assess the impact that a RTS video game may have on their task switching performance. The final section of this chapter restates the purpose of this chapter and the topics that were articulated to fulfil its purpose.

2.16 Conclusion

The purpose of this chapter was to provide a comprehensive explanation of the two focus areas of this study and motivate for this type study by identifying the gap that exists in the literature. The chapter began by defining video games, followed by comprehensive explanation of RTS video games (the first focus area of this study) and a brief description of the other video game genres that this study is concerned with. Thereafter, the various aspects of RTS video games were described in detail, to highlight the implications they have on this study and cognitive flexibility.

Next, an explanation of executive functions and cognitive flexibility was provided to foreground task switching (the second focus area of this study). Subsequently, task switching theory and its relationship to executive functions and cognitive flexibility was explored. The outcomes of previous research concerned with the effects of video games on task switching were then investigated. Finally, the gap that exists in the literature was identified followed by how this study intends to fill this gap and contribute to the body of knowledge surrounding the effects of video games on executive functions. The next chapter explains how this study was conducted by articulating the research methods, techniques and instruments selected for this study and justifying their use.

Chapter 3 - Research Methodology

3.1 Introduction

The purpose of this chapter is to present the research methods, techniques and instruments selected for this study and justify their use. In this chapter the statement of purpose and research questions will be revisited and explained in further detail. The methodology of a research project and its importance will then be briefly explained. Thereafter, the research onion derived by Saunders, Lewis, and Thornhill (2009) will be presented followed by an explanation and justification of the decisions taken in each layer of the research onion for this study. An illustration and discussion of the procedure followed to collect data will then be presented.

Subsequently, a detailed description of each research instrument will be provided. Additionally, the way in which they were implemented in this study will be explained. Afterwards, the ethical considerations for this study will be designated. Finally, the limitations of this study will be declared. This chapter begins by revisiting what this study intends to do by presenting the statement of purpose and the research questions it seeks to answer.

3.2 Statement of purpose and research questions

3.2.1 Statement of purpose

The purpose of this study is to assess the impact of Real-time Strategy games on non-playing Real-time Strategy video game players' task switching performance.

3.2.2 Research questions

- **What impact do RTS video games have on non-playing RTS VGPs' task switching performance?**

The two factors that determine task switching performance are switch costs and accuracy. The studies discussed in the literature have shown that RTS video games could have one of three impacts on task switching in this study.

The first type of impact is a positive effect on task switching performance, whereby respondents show a reduction in switch costs and increased accuracy after training in a RTS video game for a predefined number of hours over a period of time. The second type of impact RTS video games may have on task switching ability is a negative effect, where subjects display an increase in switch costs and a decrease in accuracy after RTS video game training. The third type of impact RTS video games could have on task switching performance is no effect/difference or a marginal difference between switch costs and accuracy before and after training in a RTS video game. The hypotheses for this study are recapped in table 3.1 below.

Table 3.1 - Hypotheses

Hypothesis	Statement
Null hypothesis (H0)	RTS video games have no impact on non-playing RTS VGPs' task switching performance.
Alternative hypothesis (H1)	RTS video games positively influence non-playing RTS VGPs' task switching performance
Alternative hypothesis (H2)	RTS video games negatively influence non-playing RTS VGPs' task switching performance

The answer to this research question seeks to determine what effect RTS video games have on non-playing RTS VGPs' task switching performance after receiving training in an RTS video game for a predefined number of hours over a period of time.

- **Why do RTS video games impact task switching performance in the way they do?**

The answer to this question aims to understand why the observed effect on non-playing RTS VGPs' task switching performance is occurring. To explore the possible answers, the potential explanations arising from the methodological approach used in this study will be discussed. Some methodological aspects include participants' performance within the RTS video game, the RTS video game's configuration under which subjects were made to play and the task switching test amongst others.

Additional data gathered from the sample through the questionnaire will then be scrutinized which includes experience and habits in video game genres in addition to basic demographical information. This data will be examined to determine if any these factors affect the impact that RTS video games have on non-playing RTS VGPs' task switching ability.

The previous section has restated what this study intends to do by revisiting the statement of purpose and the research questions it seeks to answer. The next section describes what the methodology of a research project is and its importance.

3.3 Methodology of research and its importance

Research methodology is concerned with how research should be carried out (Rajasekar, Philominathan, & Chinnathambi, 2006). Saunders, et al. (2009) claim that research methodology is concerned with the theory of how research should be conducted. The methodology of a research project entails the descriptions, procedures and approaches that the researchers will follow in addition to predicting phenomena in the context of a research project (Rajasekar, et al., 2006; Technology, 2014). The elaboration and justification of the chosen methods of a research project enables other researchers to understand and evaluate the results

(Technology, 2014). The goal of the methodology is for the researcher to articulate the work plan of the research project (Rajasekar, et al., 2006).

The significance of research methodology has been highlighted by various authors (Rajasekar, et al., 2006; Saunders, et al., 2009; Technology, 2014). The methodology of a study is vital because the researcher needs to be aware of which research techniques, strategies and methods are applicable to their study (Rajasekar, et al., 2006; Technology, 2014). Furthermore, it is of the utmost importance that the researcher understands the criteria by which they decide to choose the selected research techniques, methods and procedures in addition to the underlying assumptions associated with each of them (Technology, 2014). Finally, the outcome of incorporating a methodology into a research project results in a systematic approach to solving a problem (Rajasekar, et al., 2006; Technology, 2014).

Having established the need for following a methodology in research projects, the next section of this chapter details the research decisions taken in this study.

3.4 Research decisions

Saunders, et al. (2009) provide a holistic view of the research decisions, techniques, approaches and strategies that one can take in a research project in the form of the research onion. This model has been used to describe and justify each research decision taken in this study because it assists in partitioning and explaining them through its clarity and simplicity. This research onion and the decisions taken in each layer are indicated in figure 3.1 that follows.

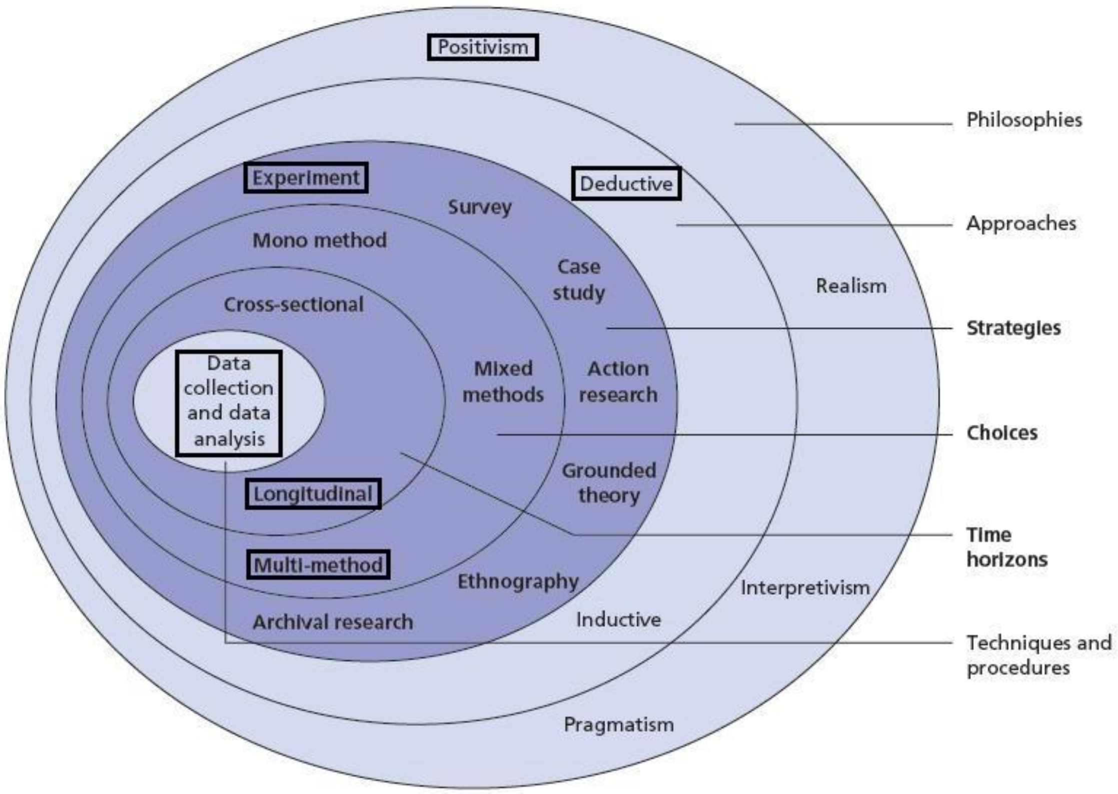


Figure 3.1 - Research onion (Saunders, et al., 2009)

3.4.1 Philosophy: positivism

In the positivist philosophy to research, only data that can be observed through the senses constitutes usable data (Macionis & Gerber, 2011; Saunders, et al., 2009). The nature of this data (also known as empirical evidence) is generated through quantifiable observations which enables statistical analysis (Macionis & Gerber, 2011; Saunders, et al., 2009).

When generating a strategy to gather empirical evidence, existing theories are usually used to produce hypotheses (Saunders, et al., 2009). The evidence collected is utilized to test and ultimately accept or reject hypotheses which lead to additional improvements of a theory (Saunders, et al., 2009). The additions to existing theory are made possible through the structured methodologies that the positivist philosophy entails, facilitating replication of previous studies (Gill & Johnson, 2002).

This study followed a structured methodology which was also followed by other studies who examined the effects of video game training on executive functions. This decision permitted the results of this study to be compared to previous studies. Furthermore, observations that are quantifiable are made through the task switching test battery (discussed in section 3.8 of this chapter) and game performance measurements (discussed in section 3.9.2 of this chapter). Finally hypotheses are formulated for this study (see table 3.1 of this chapter) which will be accepted or rejected in the analysis of the findings. These motives justify the adoption of a positivist philosophy in this study.

3.4.2 Approach: deductive

The deductive approach to research involves the creation of a theory which undergoes testing (Saunders, et al., 2009). This approach comprises several activities. The first activity is to propose a testable idea which is established from the theory, about the relationship between two or more variables (Robson, 2002). The way in which these variables will be measured is then articulated (Robson, 2002). Thereafter, a strategy is selected and utilized to test the hypothesis (Robson, 2002). The outcomes of the findings are then examined to either confirm the theory or used to suggest modifications to the theory if necessary (Robson, 2002). Finally, Saunders, et al. (2009) state that the researcher should also remain independent of what is being observed in the study.

The deductive approach to research had been selected for this study because hypotheses were created between two variables, namely, non-playing RTS VGPs task switching abilities and RTS video games. The hypotheses and the variables associated with them will be detailed and tested through the analysis of the data collected.

The conclusions drawn from the results of this study are used to accept or reject the hypotheses developed (addressed in section 4.5 of chapter four). The researcher also remained independent of the variables under inspection and did not directly or indirectly participate in the study in any way whatsoever. The research strategy selected to collect the data is addressed in the next sub-section.

3.4.3 Strategy: experiment

The goal of the experimental strategy to data collection is to investigate if a change in an independent variable yields a change in another dependent variable (Hakim, 2000; Shadish, Cook, & Campbell, 2002). The steps of a classical experimental strategy are illustrated in figure 3.2 that follows.

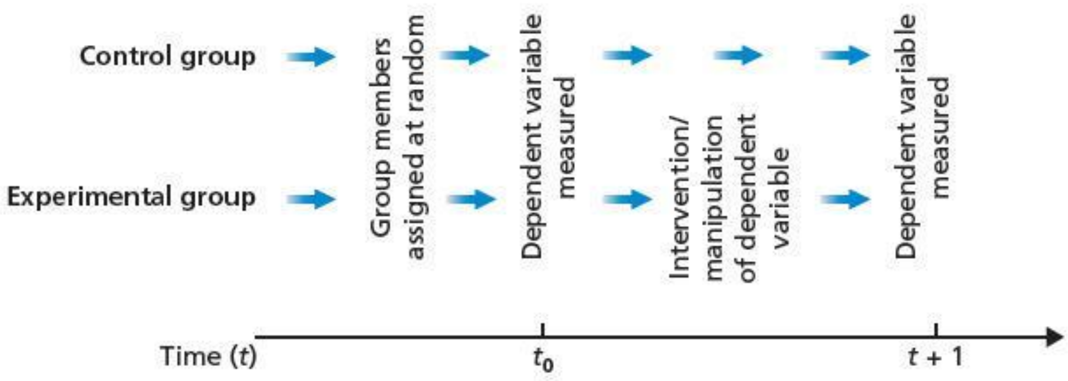


Figure 3.2 - Classical experimental strategy (Saunders, et al., 2009)

The process of experimental research usually involves the establishment of two groups; an experimental group that is exposed to the intervention measure and a control group where no intervention is made (Saunders, et al., 2009; Shadish, et al., 2002). Members are assigned randomly to either one of these groups (Saunders, et al., 2009; Shadish, et al., 2002). This ensures that the characteristics of members from both groups are identical, apart from the planned intervention that they may be exposed to (Saunders, et al., 2009). The dependent variable is measured for both the control and experimental group, before and after the implementation of the independent variable (Saunders, et al., 2009; Shadish, et al., 2002). Any differences in the dependent variable between members of both groups can then be attributed to the intervention tool (Saunders, et al., 2009; Shadish, et al., 2002).

This study employed an experimental strategy to data collection because the purpose of this study is to assess the impact of RTS video games on task switching performance. Two groups were formed; a control and an experimental group. All respondents who were identified as non-playing RTS VGPs were randomly assigned to one of these two groups (classification rules are stipulated in section 3.7.1 and 3.7.2 of this chapter).

The dependent variable (task switching) was first measured for both groups through a task switching test battery. Thereafter the experimental group trained in a RTS video game for predefined number of hours over a period of time. After exposure to the independent variable (the RTS video game) over a period of time, the dependent variable (task switching) was measured for both groups and compared to ascertain if there were any changes in task switching ability. Any changes observed in task switching abilities would be attributed to the intervention of the RTS video game.

3.4.4 Choice: multi-method

In the research onion designed by Saunders, et al. (2009), the research choice is the combination of quantitative and qualitative procedures incorporated into a research project. The combinations that Saunders, et al. (2009) describe and the method chosen for this study are illustrated in figure 3.3 below.

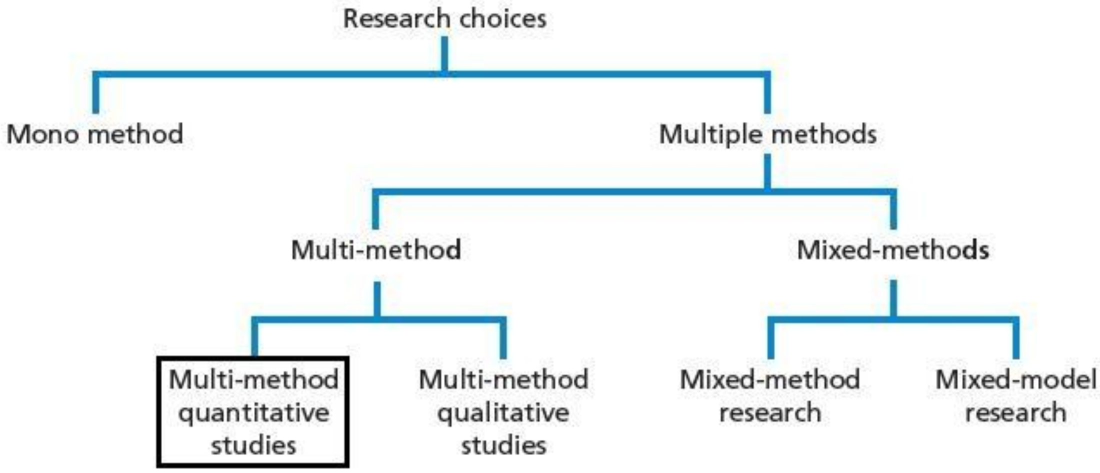


Figure 3.3 - Research choices (Saunders, et al., 2009)

In the multi-method techniques more than one data collection tool is used to gather data but the tools are restricted to either quantitative or qualitative views (Tashakkori & Teddlie, 2010).

This study utilized two quantitative research instruments to collect data: the questionnaire and the task switching test battery (these research instruments are thoroughly described in section 3.7, 3.8 and 3.9 of this chapter). Thus this study utilized the multi-method for quantitative studies. The next sub-section explains and justifies the use of a quantitative view to data in this study.

- **Quantitative**

A plethora of explanations have been developed by authors describing what quantitative approaches to research entail. Aliaga and Gunderson (2002) define quantitative research as “explaining phenomena by collecting numerical data that are analysed using mathematically based methods (in particular statistics)”. Sibanda (2009) claims that quantitative methods emphasize the gathering of numerical data and using the numerical data to make generalizations across groups of people.

The utilization of quantitative approaches over qualitative methods creates results that are neutral and easily generalizable (Boutellier, Gassmann, Raeder, & Zeschky, 2013). The consensus amongst most researchers is that quantitative methods are used when a hypothesis needs to be tested through deductive reasoning (Boutellier, et al., 2013). Furthermore, quantitative studies begin with a hypothesis and data is gathered to support it (Lubbe & Klopper, 2004).

Research instruments are developed to convert phenomena that do not exist in a quantifiable manner into quantitative data which can be analysed statistically (Muijs, 2010). Quantitative approaches to research entail the use of data collection tools such as questionnaires to generate data (Saunders, et al., 2009). To turn this data into meaningful information, quantitative analysis techniques that utilize numerical data such as statistics, tables and diagrams that depict statistics, assist in examining and establishing relationships between variables (Saunders, et al., 2009).

A quantitative view to data was incorporated into this study for several reasons. This study tests a hypothesis through a deductive approach (see table 3.1 for the hypotheses of this study). Additionally, the questionnaire research instrument identifies non-playing RTS VGPs in a quantifiable and measurable manner (explained in detail in section 3.7 of this chapter). Moreover, the task switching test battery research instrument performs mathematical calculations when determining an individual's task switching performance (see section 2.12.1 of chapter two on task switching experiment concepts). Finally, the use of a quantitative view to data assists in comparing the results of this study to the results of other studies, who also adopted quantitative views to their data.

3.4.5 Time horizon: longitudinal

The core advantage of longitudinal research over cross-sectional research is that it enables researchers to study change (Saunders, et al., 2009). By observing events over a period of time, researchers can maintain a level of control over the variables that are being investigated (G. R. Adams & Schvaneveldt, 1991). The primary focus in longitudinal studies is to observe if there are any changes in the phenomena under investigation over a period of time (Atkinson & Bouma, 1995).

This aim of this research is to examine the effects of RTS video games on a specific group of individuals who do not play RTS video games (non-playing RTS VGPs). The task switching skills of all participants were measured before and after the intervention measure. The intervention measure was the RTS video game, which participants of the experimental group played over a period of time making the longitudinal time horizon the appropriate choice.

Furthermore, the experimental strategy data collection method is run over a period of time where the dependant variable (task switching performance) is measured before and after a period of time which justifies the use of a longitudinal time horizon. Finally, the results of this study will be compared to the results of other studies that also incorporated longitudinal time horizons. These reasons make the utilization of a longitudinal time horizon appropriate for this study.

3.4.6 Data collection and data analysis

In this section the sampling technique utilized in this study will be justified followed by the reliability and validity concerns for this study.

- **Sampling technique: Snowball**

Sampling techniques that can be utilized to collect data can be divided into two types: probability and non-probability sampling. (Saunders, et al., 2009; Sekaran, 1992). With probably sampling, the chance of selecting all the various types of cases from the population is equal. Additionally, it enables researchers to answer research questions and meet research objectives that require the characteristics of the sample from the population to be estimated statistically (Saunders, et al., 2009).

With non-probability sampling techniques, the chance of selecting all the various types of cases from the population is unknown. This makes it impossible to answer research questions and meet research objectives that require statistical inferences to be made about the characteristics of the population (Saunders, et al., 2009). Generalizations about the population from the sample can still be made utilizing this sampling technique but will lack statistical support (Saunders, et al., 2009).

Snowball sampling is a special type of non-probability sampling technique that employs a method of recruiting additional subjects into the sample through current participants' acquaintances, who share similar characteristics that are of research interest (Biernacki & Waldorf, 1981; Goodman, 1961; Katz, 2006). This sampling method is used when it is difficult to assess and identify members of the population (Frank & Snijders, 1994; Katz, 2006; Saunders, et al., 2009). Current participants who identify other potential respondents usually share similar characteristics resulting in a homogeneous sample. This introduces a weakness of the snowball sampling method which is subject to biases (Given, 2008; Katz, 2006; Saunders, et al., 2009).

The whereabouts and the total size of the target population of this study remained unknown. Thus the snowball sampling method was applied to recruit as many respondents as possible. The common characteristic amongst potential respondents in this study was VGPs who did not play RTS video games. Respondents were encouraged to notify other individuals whom they knew that fit this participation criterion. These individuals were then recruited into the sample of this study. The disadvantages of this non-probability sampling method remain as limitations of this study.

Having declared the sampling method utilized in this study, the following sections examine the reliability and validity of research data particularly, the threats that exist to each of them and how each threat was managed.

- **Reliability**

The reliability of data refers to the extent to which the data collection tools produce consistent findings (Saunders, et al., 2009; Trochim & Donnelly, 2005). Robson (2002) claims that four major threats exist that may affect the reliability of all data.

Subject/participant error may occur when the time at which data gathered through some data collection tool influences responses received (Robson, 2002; Saunders, et al., 2009). In this study, the questionnaires and task switching test batteries were administered to participants during the morning of a specific day of the week only. By administering the task switching tests in the early morning period, potential factors such as fatigue and exhaustion that may have influenced respondents' task switching performance in the tests were mitigated.

Subject/participant bias occurs when an external person or factor influences participants' responses (Robson, 2002; Saunders, et al., 2009). Saunders, et al. (2009) state that responses should be kept anonymous so that they cannot be traced back to the participant. In this study, all data gathered from the questionnaires and experiment procedures remained anonymous. No other factors were identified for this study that would have encouraged participants to be biased in their responses for the questionnaire or performances in the task switching tests.

The third and fourth threats include observer error and observer bias (Robson, 2002; Saunders, et al., 2009). These occur when data gathered is interpreted in differentiating ways by other researchers. These threats are more apparent to qualitative data collection tools. Nevertheless, the data gathered in this study were analysed by two independent statisticians.[11]

Saunders, et al. (2009) has also identified the observer effect as a potential threat to the reliability of observational data collection methods. The observer effect refers to the changes in the nature of a behaviour being observed as a result of subjects being aware that they are under observation (Saunders, et al., 2009). Robson (2002) recommends a minimal interaction approach, whereby researchers attempt to have as little interaction as possible with subjects whilst they are under observation (Robson, 2002; Saunders, et al., 2009).

[11] Refer to appendix B for letters from these statisticians confirming their work on the data of this study.

In the task switching test batteries, respondents were guided through their practice blocks by the researcher to verify that the test's instructions were understood. Thereafter, the researcher left the testing venue until respondents completed the test to ensure limited interaction with them.

Mitchell (1996) advises to test for internal consistency as a method to ensure reliability of questionnaires. This test involves checking the consistency of responses across all or a sub-group of questions which is done by performing various statistical tests such as the Cronbach's alpha (Mitchell, 1996; Saunders, et al., 2009). In this study, the Cronbach's alpha statistical test was performed for the questionnaire research instrument (where appropriate) before the analysis of any data began.

The use of a structured methodology, which this study follows (as outlined in section 3.4.1 of this chapter), facilitates replication which further enhances the reliability of the data gathered (Gill & Johnson, 2002). Moreover, the questions utilized in this study's questionnaire were taken from other studies on video game training and executive function in addition to the task switching test battery acquired which has been tested and utilized extensively (permissions to utilize portions of questionnaires and the task switching test battery created by other authors is addressed in section 3.7 and 3.8 of this chapter respectively). The prior uses of these research instruments further enhance their reliability.

The subsequent section examines the validity of the research data as outlined earlier.

- **Validity**

Validity is concerned with the degree to which the correct inferences can be made from collected data (Campbell & Stanley, 1966). Two types of validity exist: internal and external. The following section addresses internal validity.

- **Internal validity**

Internal validity is the degree to which changes in variables under observation can be attributed to intervention mechanisms rather than flaws in the research design (Campbell & Stanley, 1966; Saunders, et al., 2009). Campbell and Stanley (1966), Cooper and Schindler (2008) and Saunders, et al. (2009) have recognized various threats to internal validity namely: participant selection, participant attrition/mortality, experimental history, demand characteristics and effects testing, instrument decay, experimenter effects, diffusion of treatment, compensatory rivalry and resentful demoralization and finally content validity. These threats to internal validity and the mitigation methods adopted for them are described in the following subsections.

- **Participant selection**

By giving participants the freedom of choosing which group they are assigned to in experimental studies, it is possible that an imbalanced group composition will emerge (e.g. a group comprising of males only) (Campbell & Stanley, 1966). Respondents should be randomly assigned to control and experimental groups so that any changes observed cannot be attributed to differences in group characteristics (Campbell & Stanley, 1966; Saunders, et al., 2009). In this study, respondents were randomly assigned to the control group (no RTS video game training) or the experimental group (twenty hours of RTS video game training). Random assignments were performed by allocating a unique number to each participant. The online research randomizer tool created by Urbaniak and Plous (2008) was then utilized to generate two sets of unique numbers (of equal size) for all male participants. Male subjects in the first set of unique numbers were assigned to the control group whilst male subjects in the second set were assigned to the experimental group. The same procedure was followed for female participants.

- **Participant attrition/mortality**

Participants may drop out or withdraw from the study in a non-random fashion (Campbell & Stanley, 1966; Saunders, et al., 2009). Respondents should be given the opportunity to exclude themselves from the study prior to group allocations in experimental studies (Campbell & Stanley, 1966). For ethical reasons, participants in this study were allowed to withdraw at any time without any negative consequences. In an effort to prevent participants in the experimental group from leaving, they were allowed to play the RTS video game in the way in which they desired (this is explained in more detail in section 3.9.1 of this chapter).

- **Experimental history**

Prior experiences may affect individuals' responses in experimental procedures (Campbell & Stanley, 1966). Campbell and Stanley (1966) advise to keep experiences constant for all participants. In this study, only VGPs with a minimum of ten years of video game experience to a maximum of twenty were included.

- **Demand characteristics and effects of testing**

Participants who are aware of an experiment's intention may react differently (Campbell & Stanley, 1966; Saunders, et al., 2009). Furthermore, participants will show improvement in a measurement test that is retaken (Campbell & Stanley, 1966). In addition to disguising measurement and intervention tools, the nature of participants responses to testing measures should be non-reactive and behavioural (Campbell & Stanley, 1966).

Concealing the intention of this study to participants was deemed unethical and was not possible. Moreover, the nature of the task switching test battery and RTS video game made it difficult to disguise the measurement and intervention tool.

Green, et al. (2012) highlight the problem of task-specific learning that occurs when an individual retakes a task switching test (refer to section 3.8.5 of this chapter for a brief description on task-specific learning). It was not possible to acquire more than one task switching test battery for this study. Thus demand characteristics and the effects of testing remain as limitations.

- **Instrument decay**

The effectiveness of measurement tools may change over time (Campbell & Stanley, 1966). Campbell and Stanley (1966) advise to check the reliability of the research instruments before utilizing them. This issue has been addressed under reliability later in this section.

- **Experimenter effects**

Campbell and Stanley (1966) state that it is possible for the experimenter to influence participants during testing in experiments. The experimenter should be kept blind to the hypotheses of the study and all tests should be automated (Campbell & Stanley, 1966). This could not be followed in this study and remains a limitation. However, the researcher left the testing venue for the duration of all task switching tests in an effort to limit the experimenter effects.

- **Diffusion of treatment**

In experimental studies, it is possible for treatment effects to spread from members in experimental groups to members of control groups (Campbell & Stanley, 1966). This can occur when participants in control groups become aware of the manipulation tools (Campbell & Stanley, 1966). Campbell and Stanley (1966) recommend delaying debriefing participants until they have all completed their assigned tasks. Respondents were only debriefed on the outcomes of this study after the analysis of all data collected.

- **Compensatory rivalry and resentful demoralization**

Participants in control groups (who are not exposed to the intervention measures) may portray extra motivation to perform well in measurement tests, upon learning about the intervention or manipulation tools in experimental studies (Campbell & Stanley, 1966). Alternatively, they may perform poorly in measurement tests deliberately when they know that they will not be exposed to the intervention tools (Campbell & Stanley, 1966). Participants in the control group of this study were not informed about the RTS video game training. Any communication that may have occurred between members of the control and experimental groups could not be accounted for and remains a limitation.

- **Content validity**

The extent to which the measurement tools encompass all facets surrounding a phenomenon is referred to as content validity (Cooper & Schindler, 2008). Saunders, et al. (2009) suggest to carefully define the phenomenon through a comprehensive review of the literature. Furthermore, discussion with other researchers is encouraged when appropriate and a panel of individuals may also be set up to assess the relevance of each question in the questionnaire research instrument (Saunders, et al., 2009).

As mentioned in the reliability segment of section 3.4.6 of this chapter, questions utilized in this study were taken from other studies on the effects of video games on executive functions. The questionnaire was also reviewed by two independent statisticians to confirm the relevance of each question. Finally, the literature chapter has addressed in detail, the phenomena investigated in other studies on the effects of video games on executive functions in addition to the research tools that were utilized.

The next section addresses the second type of validity as outlined earlier: external validity.

- **External validity**

External validity refers to the extent to which the results from a study can be applied to alternative populations and environments (Campbell & Stanley, 1966; Saunders, et al., 2009). Campbell and Stanley (1966) mention various threats to external validity namely: interaction of testing and treatment, interaction of selection and treatment and finally demand characteristics. These threats are addressed below.

- **Interaction of testing and treatment**

A pre-test can sensitize participants to the manipulation or intervention tool that they would be exposed to in the near future (Campbell & Stanley, 1966). This problem occurs in experiments which include pre and post-tests (Campbell & Stanley, 1966). Furthermore, participants may react differently to the intervention mechanism because they have completed pre-tests (Campbell & Stanley, 1966).

The pre-training the task switching test battery which was administered to respondents formed an essential step of the data collection process. It was difficult to conceal or disguise this step since participants were fully aware of the purpose of the study. Thus the testing and treatment interactions remain as limitations to the external validity of the results in this study.

- **Interaction of selection and treatment**

This may occur when the effects of the intervention tool is found for only a particular group of participants in the experimental study (Campbell & Stanley, 1966). This threat becomes greater as the difficulty of finding potential respondents increases (Campbell & Stanley, 1966). The snowball sampling method makes this study more prone to the selection and treatment threat to external validity. Thus, this threat remains as a limitation to the generalizability of the findings and results of this study.

- **Demand characteristics**

This threat to external validity also exists for internal validity and has been addressed in the internal validity section.

The next section explores additional techniques to enhance the reliability and validity of data generated from research instruments.

- **Additional enhancement methods for reliability and validity**

As a final note on reliability and validity, Campbell and Stanley (1966) suggest various other methods to enhance the reliability and validity of gathered research data. One method is to replicate other studies (Campbell & Stanley, 1966). By replicating previous experiments and studies following identical procedures, additional reliability and confidence can be placed on the results (Campbell & Stanley, 1966). Moreover, replication with extension aims to confirm previous findings in alternative settings or with different populations (Campbell & Stanley, 1966). This study attempts to replicate previous experiments with an extension by examining the training effect of RTS video games on a population that has not been examined before (non-playing RTS VGPs).

Another method to further enhance the reliability and validity of data is to conduct pre-testing of experimental measurement tool (Campbell & Stanley, 1966). Pre-testing the experiment before beginning data collection assists in confirming that the results of the experiment are what they claim to measure (Campbell & Stanley, 1966). For this study, the task switching measurement tool was tested before data collection to confirm that it accurately measured reaction times, switch costs and task switching performance.

Finally, a pilot study which is a much scaled down version of the research, aids in testing and understanding the procedures that will be followed throughout the data collection process

(Campbell & Stanley, 1966). The questionnaire and task switching test battery were administered to a few individuals who were not eligible to participate in this study prior to data collection. This procedure was followed to improve the external validity of the data generated from the research instruments.

Having described the research decisions and the research questions this study seeks to answer, the following sections will stipulate where the data was collected from and the procedure followed to analyse the data in this study.

- **Data collection location**

Most of the potential respondents were expected to be found at the UKZN Westville campus (at the convenience of the researcher) and as such questionnaires were administered there. Questionnaires were also handed out to participants outside the UKZN campus who qualified to participate in this study and were recruited. The task switching test batteries were held at a specific LAN at UKZN for every participant to ensure testing conditions remained homogenous. The RTS video game (StarCraft) was played on participants' personal computers.

- **Data analysis**

All data generated from the questionnaires and task switching test batteries were captured into SPSS. The utilization of SPSS facilitated statistical analysis of the data and investigation of potential relationships between the research variables. The statistical analysis was conducted by two independent statisticians[12].

The previous sections outlined where participants were recruited from and the procedure followed to analyse all collected data. The subsequent section stipulates the procedures and steps followed to gather the data in this study.

- **Data collection process**

The steps and procedures followed to gather data in this study are illustrated in figure 3.4 that follows.

---

[12] A letter confirming the analysis of data from two independent statisticians can be viewed in appendix B.

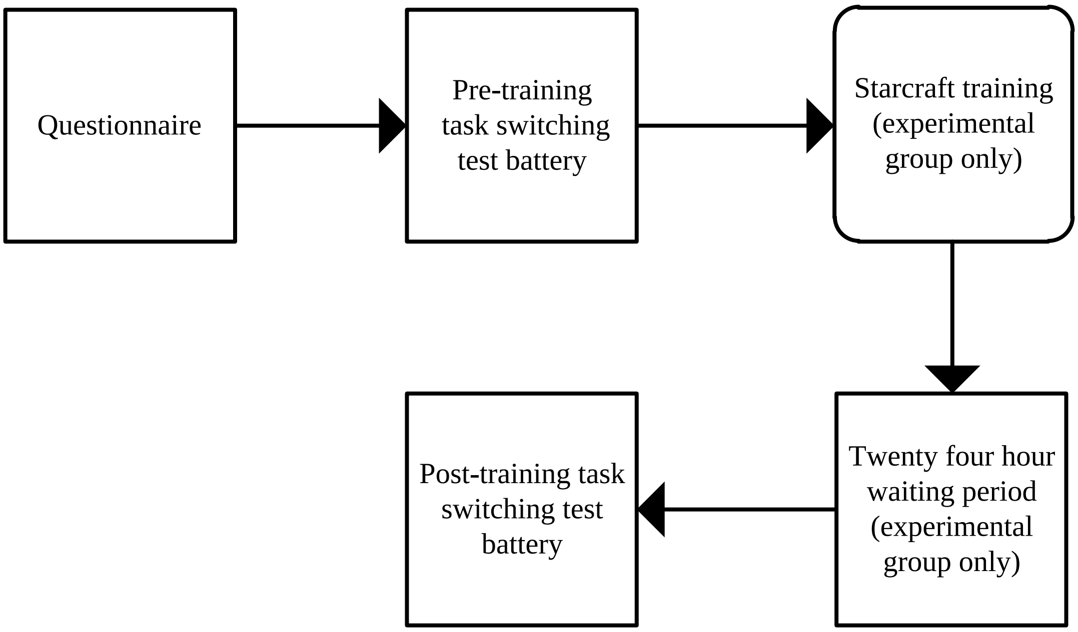


Figure 3.4 - Data collection process[13]

A pre-experiment questionnaire was first administered to potential participants before recruiting them into the study. This questionnaire identified non-playing RTS VGPs, their video game experience and usage in each video game genre. This study focuses on the effects of RTS video games on non-playing RTS VGPs task switching performance making the pre-experiment questionnaire pivotal in identifying this particular group of individuals.

After administering the questionnaires, subjects were randomly assigned to one of two groups: the control group or experimental group. Respondents in the control group were not exposed to any intervention or manipulation tools for the duration of the study. Subjects in the experimental group were introduced to the intervention tool, the RTS video game StarCraft, and underwent training in this video game for a period of twenty hours (the decision to have subjects in the experimental group train for twenty hours is justified in section 3.6 of this chapter).

Before any training commenced, a pre-training task switching test battery was completed by all participants. This test assessed their ability to switch between two distinct tasks effectively. Thereafter, the experimental group commenced training in the RTS video game in addition to their normal video gaming habits, whilst the control group continued their routinely video gaming habits without any exposure to RTS video games (the setup of the StarCraft is explained in detail in the section 3.9 of this chapter). The duration of training schedule was run over a period of four to six weeks (the duration of the schedule is explained in further detail in section 3.6 of this chapter).

[13] Adapted from Green, et al. (2012) and Glass, et al. (2013)

Green and Bavelier (2012) recommend a twenty-four hour waiting period after the last training session to ensure that any changes observed are not due to temporary changes in psychology or arousal. This twenty four hour waiting period was followed by before respondents in the experimental group undertook the post-training task switching test battery. Participants in the control group also completed a second task switching performance test at this time.

In this section the data collection process was explained in detail to notify the reader of the steps and procedures followed to collect data in this study. The following section will analyse the population and sample sizes to establish the size of the sample chosen for this research. This will be performed by comparing the sample sizes used in other studies to justify the sample size used in this study.

3.5 Sample Size

Table 3.2 that follows lists the sample sizes selected in other studies on video game training and its effects on executive functions. The size of each group, the gender distribution, mean age and populations has also been specified.

Table 3.2 - Sample sizes of other studies

Study	Number of groups	Group characteristics						
		Name	Size: Gender: Males	Size: Gender: Females	Size: Total	Mean age	Population	Video game used
Boot, et al. (2008) - longitudinal experiment	4	A	19	0	19	21.40	nVGPs	None
		B	2	18	20	21.35		MoH
		C	2	18	20	21.50		Tetris
		D	3	20	23	21.74		RoN
Boot, et al. (2008) - cross-sectional groups	2	X	11	0	11	21.10	VGPs	N/A
		Y	10	0	10	22.20	nVGPs	
Basak, et al. (2008)	2	A	5	15	20	70.05	nVGPs	RoN
		B	5	15	20	69.10		None
Green, et al. (2012) – experiment one	2	A	8	0	8	18.7	AVGPs	N/A
		B	10	0	10	19.9	nAVGPs	
Green, et al. (2012) – experiment two	2	A	14	0	14	20.6	AVGPS	N/A
		B	14	0	14	Not specified	nAVGPs	
Green, et al. (2012) – experiment four (training)	2	A	8	11	19	25.7	nVGPs	UT 2004 CoD 2
		B	4	13	17	24.7		The Sims 2
Glass, et al. (2013)	3	A	0	26	26	20.3	nVGPs	StarCraft (SC-1 game setup)
		B	0	20	20	20.4		StarCraft (SC-2 game setup)
		C	0	26	26	19.9		None

The sample size chosen for a study investigating the effects of action video game training on attentional capture was thirty two (Chisholm, Hickey, Theeuwes, & Kingstone, 2010). The mean age of this sample was 21.3 which were all male.

In this study two groups were formed for the experiment: a control and an experimental group. The population that this study looks at are non-playing RTS VGPs. The population size of non-playing RTS VGPs is difficult to determine and is therefore unknown. It was expected to experience difficulty in recruiting a high number of respondents to participate in this study. Thus a minimum sample size of thirty two subjects was used in this study which is equivalent to the sample size of the study conducted by Chisholm, et al. (2010). Eligible respondents that pushed the sample size beyond the minimum were welcome to participate.

In some of the studies listed in table 3.2 such as experiment one and two of the study conducted by Green, et al. (2012), no females formed part of the sample due to the scarcity of females with the appropriate video gaming experience. For this study both males and females were recruited which facilitated analysis of gender differences in video game training and executive functions.

The mean age of the sample sizes in the studies in the literature (listed in table 3.2) was between twenty and twenty five (apart from the study conducted by Basak, et al. (2008) who examined the training effects of video games on older adults). The mean age of the sample in this study was kept between these numbers (twenty and twenty five) to facilitate the comparison of the findings in this study to the findings of the studies in the literature.

The next segment lists the number of hours and the duration of training schedules that subjects underwent in other studies. Thereafter, the number of hours that participants trained for in this study will be stated and justified.

3.6 Training hours and schedule

The total time that respondents have trained for in video games differs across studies. The training studies discussed in the literature and their training schedules are listed in table 3.3 below.

Table 3.3 - Training schedule

Study	Number of hours trained	Duration of training schedule
Boot, et al. (2008)	Fifteen training sessions. Total practice time of twenty one and a half hours	Four to five weeks
Basak, et al. (2008)	Fifteen one and half hour training sessions resulting in twenty three and a half hours of total training time	Seven to eight weeks
Green, et al. (2012)	Fifty hours of video game training	Six to fourteen weeks
Glass, et al. (2013)	One hour per day. Total of forty hours of practice	Seven weeks
This study	Twenty hours of video game training	Four to six weeks

Respondents in this study participated for no monetary gain or benefit making it difficult to incentivise participants to train over an extended period of time. Thus the lowest number of training hours required and a training schedule with the shortest acceptable duration was implemented. The number of hours participants in the experimental group trained for in this study, followed the example set out by Boot, et al. (2008). Hence, subjects in the experimental group were trained for a total of twenty hours in StarCraft.

The number of playing sessions each participant played in the study by Boot, et al. (2008) were not strictly followed. Scenarios in StarCraft can vary in time and length. As a result of this, participants were instructed to reach their target of twenty hours, regardless of the number of training sessions it took to reach this total.

The duration of the training schedule followed a combination of the studies (listed in table 3.3) and was run over a period of four to six weeks. This decision was taken because participants trained in the RTS video game for twenty hours. Allowing this twenty hour target to be reached over longer periods would translate into fewer hours being invested by participants to play the RTS video game every day. This in turn, may reduce the impact of the video game on task switching performance.

The previous sections detailed the data collection process, sample size and RTS video game training regime. All the research instruments which were utilized in this study will now be described in detail. The next section articulates the structure and derivation of the first research instrument: the questionnaire.

3.7 Questionnaire

Surveys and questionnaires used in other studies concerned with the effects of video game experience on executive functions were requested from various authors. Numerous responses were received from authors who provided surveys, test batteries and other tools used in their studies. The questionnaire utilized in this research is an adaptation of the questionnaires constructed by Butler and Dee (2012), Cain, et al. (2012) and Green, et al. (2012).[14]

The questionnaire consisted of three sections (A, B and C) which can be viewed in appendix A. Table 3.4 below provides an overview of the questionnaire by listing the sections of the questionnaire, the number of questions in each section, the data collected from each section and the purpose of the data collected.

Table 3.4 - Questionnaire overview

Section	Number of questions	Data Collected	Purpose of Data
A.	Five.	Basic Demographics.	Ethical requirements (over the age of eighteen).
	Two.	Video game usage.	Identify VGPs.
B.	Ten.	Hourly usage per video game genre.	Identify non-playing RTS VGPs.
		Expertise per video game genre (on a scale of one to seven.)	Establish subjects' expertise in video gaming genres.
C.	Eight.	Multitasking activities whilst studying or working alone.	Explore subjects' multitasking habits outside video games.
	Eight.	Multitasking activities whilst studying or working in a group.	
	Eleven.	Multitasking activities whilst driving.	

[14] Permissions were obtained from Butler and Dee (2012), Cain, et al. (2012) and Green, et al. (2012) to utilize their data gathering tools and credit is given to them here.

Section A of the questionnaire requested basic demographic data from respondents such as age, gender, name and race. Their average video game usage per week for the past six months were also requested in this section. This was done to differentiate between VGPs and nVGPs because this study examined the effect of RTS video games on current VGPs' task switching performance.

Section B of the questionnaire listed all the video gaming genres, requesting the respondent to indicate their expertise in each genre and the number of hours they play per week for each genre in the past six months. It was important to distinguish non-playing RTS VGPs from RTS VGPs as this study examined the training effect of RTS video games on non-playing RTS VGPs' task switching performance. Additionally, respondents' video gaming habits and exposure were analysed to explain the outcomes of this study.

Section C of the questionnaire requested subjects' multitasking and task switching behaviours whilst studying or working alone, studying or working in a group and whilst driving if they did so. These behaviours were investigated to further explore respondents' task switching habits.

Authors have differed on how individuals are categorized as VGPs or nVGPs. The next section will examine their categorizations and explain how this study has differentiated between VGPs and nVGPs.

3.7.1 Categorization of VGPs and nVGPs

Authors amongst the studies that have examined the effects of video games on executive functions (discussed in chapter two) have conflicting opinions on distinguishing VGPs from nVGPS. In table 3.5 that follows, each study is listed with their categorization rules for VGPs and nVGPs.

Table 3.5 - Categorization rules for VGPs and nVGPS

Study	Categorization as VGP		Categorization as nVGP	
	Number of hours	Time Period	Number of hours	Time Period
Boot, et al. (2008)	Greater than or equal to seven hours of video game usage per week	Past two years	Less than or equal to one hour of video game usage per week	Past two years
Basak, et al. (2008)	N/A	N/A	Zero hours of video game usage per week	Past two years
Glass, et al. (2013)	N/A	N/A	Less than two hours of video game usage per week	Unspecified
Colzato, et al. (2010)	Four times/sessions per week. Hours per session were unspecified	Past six months.	N/A	N/A
Cain, et al. (2012)	Six hours or more of video game usage (primarily action based games) per week. Ranked five or more for expertise in FPS or action based games	Unspecified.	Less than two hours of FPS and action video game usage per week. Ranked two or less for FPS expertise	Unspecified.
Butler and Dee (2012)	N/A	N/A	N/A	N/A

A discrepancy in the categorization rules can be seen in the study conducted by Cain, et al. (2012). According to Cain, et al. (2012) VGPs are classified according to their action-based video game usage only. This is not entirely correct as experience and usage in other video game genres should not disqualify an individual from qualifying as a VGP.

The way this study classifies VGPs is derived from a combination of categorization rules utilized in other studies on video game effects and executive functions. For the amount of video game usage per week, this study followed the method used by Cain, et al. (2012) with a slight adjustment. VGPs were classified as individuals who reported six hours or more of video game usage per week in any combination of video game genres. The classification of VGPs by Cain, et al. (2012) was chosen for this study because the question which categorizes VGPs and nVGP in this study's questionnaire was derived from their research instrument amongst two others.

Cain, et al. (2012) does not specify the duration for this usage as depicted in table 3.5. Thus the time period for this usage followed the categorization rules stipulated by Green, et al. (2012) (rules shown in table 3.6) and Colzato, et al. (2010) which was the past six months. Their time periods were chosen because the question which categorizes VGPs and nVGP in this study's questionnaire was derived from the questionnaire utilized in the study by Green, et al. (2012) amongst two others.

This study aims to examine the effect of RTS video games on non-playing RTS VGPs' task switching performance. The next section will discuss how this this study categorizes genre-specific VGPs by investigating how another study has classified them.

3.7.2 Categorization of genre-specific VGPs

Only one study in the literature has been found that has designated rules for a VGP to qualify as VGP in a specific video game genre (e.g. RTS VGP) and this study will use similar criteria to classify genre-specific VGPs. The classification rules of the study conducted by Green, et al. (2012) are listed in table 3.6 below.

Table 3.6 - Categorization rules for genre-specific VGPs

Study	Categorization as genre-specific VGP		Categorization as genre-specific nVGP	
	Number of hours	Time Period	Number of hours	Time Period
Green, et al. (2012) (Experiment 1)	Greater than or equal to five hours of genre-specific video game usage per week.	Past six months.	Zero hours of genre-specific video game usage per week.	Past six months.
Green, et al. (2012) (Experiment 2)	Greater than or equal to five hours of genre-specific video game usage per week.	Past year.	Zero hours of genre-specific video game usage per week.	Past year.

This study will follow the example set out in the first experiment of Green and colleagues' (2012) paper and categorize non-playing RTS VGPs as participants who report no video game usage per week (zero hours) in RTS video games over the previous six months. The time period of six months was chosen to correspond with the time period of VGP classification.

Table 3.7 below summarizes the rules to qualify for participation in this study.

Table 3.7 - Qualification rules

Rules to be included in the study	Reasoning
Above the age of eighteen.	Ethical requirements (explained in section 3.10 of this chapter).
Report playing video games for six hours or more per week in the last six months.	This study examined current VGPS.
Report no RTS video game usage (zero hours per week) in the last six months.	Non-playing RTS VGPs' multitasking habits and task switching performance were investigated.

Each potential respondent answered the three questions relating to age, video game usage and RTS video game usage which were included the questionnaire. Subjects who did not match the specified criteria (listed in table 3.7) were thanked for their time and were not recruited for participation in this study.

The second research instrument utilized in this study was the task switching test battery. This measurement tool will now be illustrated and reviewed in detail as delineated earlier.

3.8 The task switching test battery

Table 3.8 below lists the task switching measures implemented in the studies discussed in the literature review chapter.

Table 3.8 - Task switching test measures of other studies

Study	Stimuli	Task 1	Task 2
Video game training studies			
Boot, et al. (2008)	A single number ranging from one to nine (excluding five)	Judging if the number is odd or even	Judging if the number is smaller of greater than five
Basak, et al. (2008)	A single number ranging from one to nine (excluding five)	Judging if the number is odd or even	Judging if the number is smaller of greater than five
Green, et al. (2012)	A single object that was either a circle or square. The colour of the shape was blue or red	Judging the colour of the object	Judging the shape of the object
Glass, et al. (2013)	One alphabetical letter (a, e, i, o, u, p, k, n, s) and one number ranging from two to nine	Judging if the alphabetical letter is a vowel on consonant	Judging if the number is odd or even
Non-training video game studies			
Colzato, et al. (2010)	Geometric figures- Square or rectangle made up of smaller squares or rectangles	Judging if the bigger shape is a square or rectangle	Judging if the smaller shapes that make up the bigger shape are squares or rectangles
Cain, et al. (2012)	Three arrows pointing either right or left presented adjacent to each other	Judging the current direction the centre arrow is pointing	Judging the opposite direction the centre arrow is pointing
Butler and Dee (2012)	Wisconsin Card Sorting Test	Judging the shape of the figure on a card	Judging the shading of the figure on a card

Two of the video game training studies utilized a task switching test measure that required participants to judge if a number between one and nine (excluding five) was odd/even or greater/less than five. Based on the results of these tests, the authors assessed participants' task switching performance and drew conclusions about the effects of video game training on task switching abilities.

These task switching test measures involved a number task which proves that it is indicative of task switching abilities. Thus this study utilized a similar task switching test measure whereby subjects identified if a number was odd/even or higher or greater than a specified number.

Furthermore, the results of this study are compared to the results of the studies in the literature which further justifies its use.

3.8.1 User interface and example task-set

The software that the task switching test utilized in this study was written in metacard and provided by Brooklyn College of the City University of New York (CUNY) which is used in their experimental psychology course. Figure 3.5 below illustrates the user interface of the task switching test battery and an example of a trial currently on screen awaiting the participant's response.

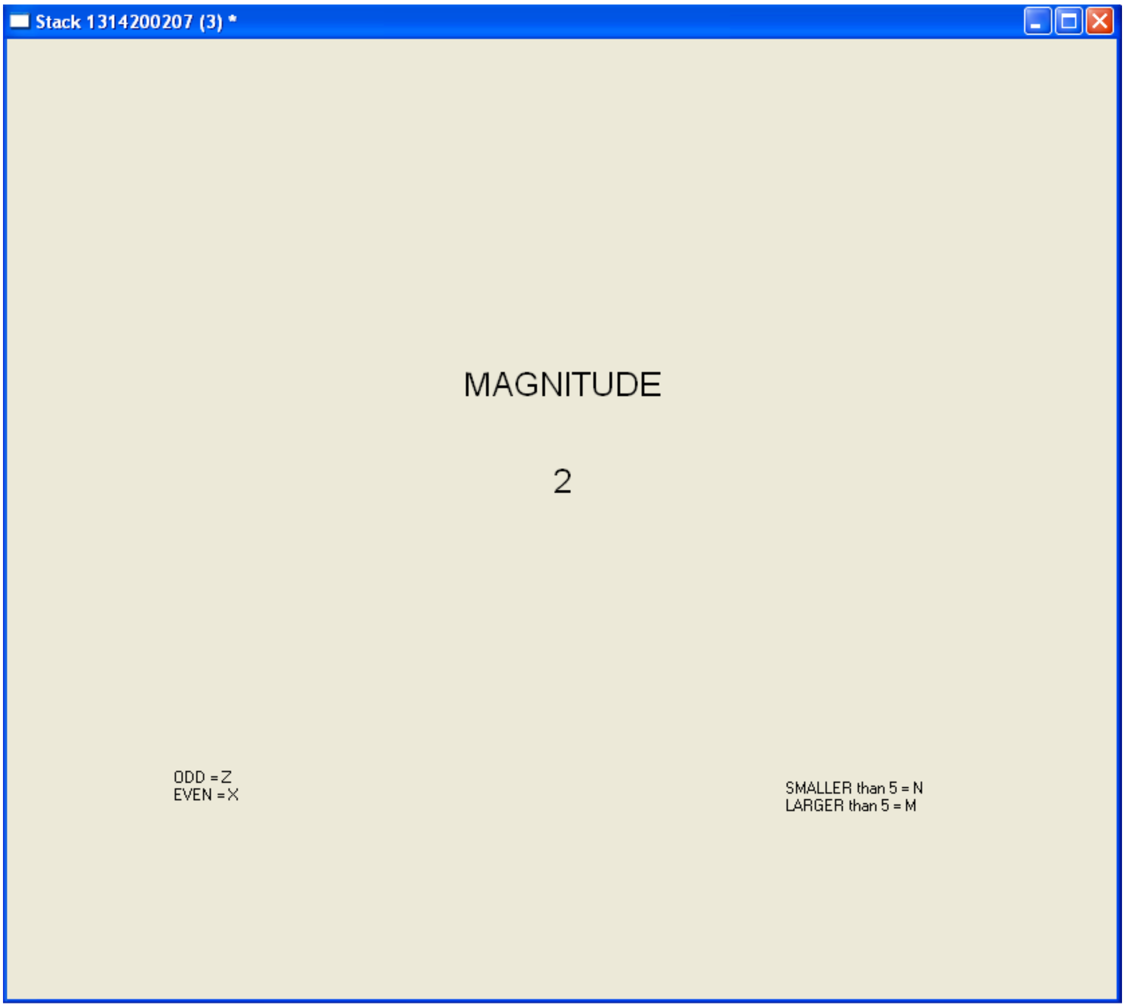


Figure 3.5 - User interface of the task switching test battery

Figure 3.6 that follows illustrates an example of a set of trials that a subject was required to complete.

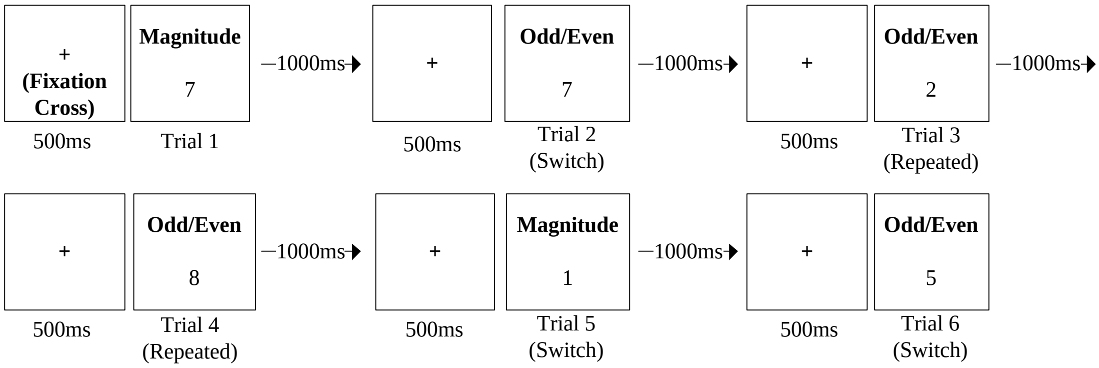


Figure 3.6 - Task-set example

Participants were required to identify if a number was above or below five, or if the number was odd or even. The task cues were displayed with the target stimuli. If the word magnitude was displayed, subjects needed to identify if the number was above or below five. If the words odd/even were shown, participants needed to recognize if the number was odd or even. Eight possible target stimuli were displayed namely: one, two, three, four, six, seven, eight and nine.

The trials were alternated such that fifty percent of them were magnitude trials and fifty percent were odd/even trials. Furthermore, the task switched on fifty percent of the trials and the task repeated for the other fifty percent of the trials. Finally, the order of trials was fully randomized for each participant.

A fixation cross was displayed on screen for five hundred milliseconds before each trial. Then the task cue and target stimuli were displayed simultaneously until a response was given. A one thousand millisecond delay followed the response made for each trial. As demonstrated in figure 3.5 the response mappings remained on screen at all times during the task switching test battery. The response mappings of the task switching test battery are listed in table 3.9 below.

Table 3.9 - Response mappings

Key	Identification
Z	Odd
X	Even
N	Smaller than five
M	Larger than five

The results of the task switching test battery displayed four figures which were categorized into two groups. The first set of results calculated the mean response times of all trials in milliseconds. One value was the response time calculated for trials that were repeated (same task as previous trial) and the other was for reaction times on switch trials (different task as previous trial). The second set of results calculated error rates. The first value displayed the errors that a subject may have made when completing repeated trials whilst the second value displayed the errors a subject may have made when performing switched trials.

The next sub-section examines the special instructions that can be given to subjects in task switching tests and the impact that these instructions may have on their performances in task switching test measures.

3.8.2 Special instructions

In one of the experiments conducted by Green and colleagues (2012), participants were instructed to focus on accuracy over speed in their responses before undertaking the task switching tests. This special instruction was noted to have an impact on the results. All other studies examined and discussed in chapter two did not include any special instructions to participants before undertaking task switching tests batteries.

This study will follow the example of the majority of the studies and did not give participants any special instructions before undertaking the task switching test battery. The decision to improve accuracy at the cost of slower response times or attempting to achieve quicker response times whilst forgoing accuracy was left to each participant to decide intuitively. This kept the results of the task switching test battery in this study comparable to the results of the task switching test measures in the other studies surrounding the effects of video games on executive functions. Furthermore, special instructions impact participants' performances in task switching test measures as demonstrated by Green, et al. (2012). Comparing the results of the task switching test battery with and without special instructions falls outside the scope of this study.

Task switching test batteries used in other studies have adopted various task switching paradigms. The next section will compare the paradigms used in their task switching test measures followed by the task switching paradigm utilized in this study's task switching test battery (for an overview on task switching paradigms, refer to the task switching section in chapter two).

3.8.3 Task switching paradigm

Monsell (2003) has provided several task switching paradigms that may be used in task switching experiments which have been discussed in chapter two (see section 2.12.2). The task switching paradigms used in the task switching test measures of the studies in the literature have varied. Table 3.10 that follows lists the studies and the task switching paradigms they have used in their task switching tests

.

Table 3.10 - Task switching paradigms of other studies

Study	Task switching paradigm
Training video game studies	
Boot, et al. (2008)	Task-cueing paradigm.
Basak, et al. (2008)	Task-cueing paradigm.
Green, et al. (2012)	Alternating-runs paradigm.
Glass, et al. (2013)	Unspecified.
Non-training video game studies	
Colzato, et al. (2010)	Alternating-runs paradigm.
Cain, et al. (2012)	Task-cueing paradigm.
Butler and Dee (2012)	N/A

This experiment will follow the task switching paradigm used in most of the studies discussed and utilize the task-cueing paradigm. Additionally, the task-cueing paradigm attempts to simulate the type of task switching that occurs in RTS video games.

In the initial stages of a skirmish in StarCraft, players focus on the same set of tasks which involve the gathering of resources, production of SCVs (for Terran), drones (for Zerg) or probes (for Protoss) and scouting the environment to gather intelligence on their opponents' actions (refer to defending vulnerable items and units portion of gameplay challenges in section 2.6.1 of chapter two for the functions that these units perform and section 2.7.1). As the game progresses players' actions become unpredictable as they perform varying tactical actions in response to their opponents' activities.

For example, a player's tactics could shift from performing tasks related to resource gathering and base expansion in the initial stages of the skirmish to the construction of military units for the purposes of defending their structures based on an impending attack. Tasks at this stage of the game would now be based on their opponent's activities and would remain unpredictable for the remainder of the scenario. Thus, the task-cueing paradigm corresponds with the type of task switching that occurs for the majority of a StarCraft scenario.

Having examined the task switching paradigm utilized in this study's task switching test battery, the number of practice blocks, experimental blocks and trials in each block of task switching tests which has varied across studies will now be examined. Additionally the number of blocks and trials used in this study's task switching test battery and how these numbers were derived will be explained.

3.8.4 Number of practice, experimental blocks and trials

Table 3.11 that follows lists the studies concerned with the effects of video games on executive functions and the number of practice blocks and experimental blocks implemented in their task switching test measures. The number of trials in each block has also been included followed by an explanation of the blocks and trials implemented in this study's task switching test battery.

Table 3.11 - Practice, experimental blocks and trials of other studies

Study	Practice Blocks		Experimental Blocks	
	Number of trials	Number of blocks	Number of trials	Number of Blocks
Boot, et al. (2008)	Thirty	Four Single-task blocks	One hundred and sixty	One
	Thirty	One dual-task block		
Basak, et al. (2008)	Thirty	Four Single-task blocks	One hundred and sixty	One
	Thirty	One dual-task block		
Green, et al. (2012) (experiment one)	None	None	Three hundred and twenty	Two (vocal responses)
	None	None	Three hundred and twenty	Two (keyboard responses)
Green, et al. (2012) (experiment two)	One hundred and twenty eight	One	Three hundred and twenty	One (cognitive task)
			Three hundred and twenty	One (perceptual task)
Green, et al. (2012) (experiment four)	Three hundred and twenty	Two	Three hundred and twenty	Two
Glass, et al. (2013)	Unspecified	Unspecified	Unspecified	Unspecified

Green, et al. (2012) recommend keeping testing sessions as short as possible when examining the training effect of an alternate training task on task switching performance (Green, et al., 2012). Thus, respondents completed one practice and one experimental block in this study's task switching test battery.

Subjects were guided through the instruction page before the practice block. Participants completed one practice block consisting of twenty five trials. Respondents were advised on the correct keyboard responses during the practice block. The results from these trials were not recorded. Thereafter, one experimental block, consisting of one hundred trials was completed by each subject. These results were recorded and analysed.

The frequency of tests on executive functions that have been conducted have differed across experiments in other studies. The next section compares the frequency of tests on executive functions in the other video game training studies and discloses the frequency of the tests on task switching performance administered in this study.

3.8.5 Frequency of tests on executive functions

The studies that examine the effects of video game training on executive functions are listed in table 3.12 that follows along with the frequency at which participants were made to complete tests that assess their performance in various executive functions.

Table 3.12 - Frequency of executive function tests in other studies

Study	Frequency of tests on executive functions		
	Pre-Training	Halfway through training	Post-training
Boot, et al. (2008)	✓	✓	✓
Basak, et al. (2008)	✓	✓	✓
Green, et al. (2012)	✓	×	✓
Glass, et al. (2013)	✓	✓	✓

It can be seen from table 3.12 that Green, et al. (2012) limited their tests measuring executive function performance to pre and post-training. According to Green, et al. (2012) testing an individual repeatedly on the same task increases the probability of task-specific learning and the best way to improve on a particular task is to repeatedly train on that very same task. Moreover, it is advised to keep testing sessions to a minimum when examining the training effect of an alternate training task on task switching performance (Green, et al., 2012).

Thus, the task switching tests in this study were limited to pre and post-training. This decision also assisted in mitigating the effects of testing to the internal validity of the data generated from the task switching test battery (see section 3.4.6 on threats to internal validity and the mitigation techniques adopted in this study).

The RTS video game StarCraft: Brood Wars, developed by Blizzard Entertainment served as the intervention tool in this study. Although a sequel game, StarCraft II has been developed, it was not used due to the higher inherit overheads and always-on internet connection that is required to play game. The next section provides a brief description of StarCraft to provide the reader with some background knowledge on this video game and why it has been chosen for this study. Furthermore, the various video game elements of StarCraft will be described and how they were configured for this study.

3.9 Game: StarCraft: Brood Wars

Many researchers have used StarCraft: Brood Wars (an RTS video game) in their studies. A few of the concepts that have been looked at with StarCraft are: network analysis (Claypool, LaPoint, & Winslow, 2003), map generation (Togelius, et al., 2010), build order optimizations (Churchill & Buro, 2011), strategy prediction (Park, Lee, Cho, & Kim, 2012) and micromanagement (Svendsen & Rathe, 2012) amongst numerous others. Furthermore a recent study by Glass, et al. (2013) who assessed the training effects of video games on cognitive flexibility, utilized StarCraft as the intervention mechanism.

The significance of StarCraft in video game history has been recognized by a myriad of video game experts with video game reviewers recognizing StarCraft as one of the most successful video games of all time and one that set the standard of how video games in its genre should be developed (Edge, 2007; Fatt & Gamepro, 2007). The utilization of StarCraft in numerous research projects which explore various facets together with the other aforementioned reasons make the use of this RTS video game appropriate and relevant to this study.

StarCraft is a RTS video game developed by Blizzard Entertainment in 1998 which is set in a fictitious galaxy. The object of the game is for a player to gather resources (minerals and Vespene Gas), create military units and structures, research technologies and ultimately eliminate all enemies units and buildings whilst preserving their own assets. The events of the game's plot occurs during the twenty fifth century which takes place in a remote part of the galaxy known as the Koprulu Sector.

There are three races that are playable which are involved in the game's plot. The Terran are humans with psionic potential that have been exiled from earth. They are skilled at adapting to any situation in order to survive. The Zerg are a race of terrifying and ruthless amalgamations of biologically advanced arthropod aliens who are dedicated in their pursuit of genetic perfection and assimilation of other species. Finally, the Protoss are a sapient humanoid race who use advanced technology and psionic mastery to preserve their civilization whilst following a strict philosophical way of living.

Each race within StarCraft has its own unique traits, abilities, strengths and weaknesses. For example, the Terran's units and buildings have an average cost. Their units are generally fragile but are capable of dealing significant amounts of damage. The Zerg have low cost units that are not as powerful as the units of the other races. The strength of their units comes from the low population that they consume and their quick production times, giving this race the ability to swarm and overrun opponents with speed and overwhelming numbers.

Each Protoss unit requires more resources to build and count more towards the population limit in comparison to the other races. Thus, the total number of units that the Protoss race are able to produce in comparison to the other races are much fewer. However, their units have high attack power and health. Furthermore, all Protoss units and buildings are equipped with plasma shields that recharge over time giving the Protoss an additional layer of defence (Refer to figure 2.2 of chapter 2 for a screenshot of the StarCraft user interface and appendix D for unit descriptions and the concept of population).

The game setup of StarCraft for this study will now be specified to inform the reader of the exact gaming environment participants were made to play in. First, the game setup of RTS video games used in other studies will be compared and examined in detail (the study conducted by Green and colleagues (2012) trained participants in a FPS video game and their game setup is therefore not applicable to this study). Thereafter, the game setup derived and used in this study will be outlined.

3.9.1 Game setup

Three aspects of the game setup in StarCraft will be examined in this section. The first aspect that will be reviewed is the scenario settings of the game. The scenario settings include settings such as the terrain, total resources and size of the battle's location. The second aspect, race selection, will then be explored. RTS video games usually include various races or nations that can be selected that have distinct strengths and weakness that suit different strategies (refer to the previous section for a brief summary of the races and their distinct traits in StarCraft). Finally, the difficulty settings which can be adjusted in RTS video games will be outlined. Each aspect of the game setup will first examine how other studies concerned with the effects of video games on executive functions have implemented them, followed by how this study enforced each setting.

- **Scenario settings**

As mentioned earlier, the scenario settings of the RTS video game include settings such as the terrain, total resources and the size of the battle location or map in a skirmish. The settings implemented in the video game training studies discussed in the literature will be examined followed by the scenario settings enforced for StarCraft in this study.

Although not explicitly stated, the authors' descriptions in the study by Boot, et al. (2008) suggest that the "survival of the fittest" scenario in RoN was played. In this mode no alliances can be formed between nations but contains various paths to victory. The terrain and landscape differed in every skirmish (Boot, et al., 2008).

In another study conducted by Basak, et al. (2008), participants were also instructed to play "survival of the fittest" scenario in RoN. The authors' state that each game's setting was pre-set and remained fixed for all players. The exact details of these settings were not specified. However, the authors did mention that the terrain of each skirmish varied following a predetermined rotation (Basak, et al., 2008).

Glass, et al. (2013) who utilized StarCraft in their study, created two different scenarios designed for groups to play: a half-map version and a full-map version of StarCraft. Both these scenarios were a one-versus-one skirmish against a computer-controlled opponent.

The full-map contained two friendly bases and two enemy bases from the beginning of the scenario. In this scenario, players commanded two separate bases on different areas of the map and engaged in multiple battles against the opponent's two bases (Glass, et al., 2013). Glass, et al. (2013) claim that this situation promoted more task switching and coordination of cognitive resources than the half-map version (Glass, et al., 2013).

The half-map version involved the game's default beginning of providing one base for the player and one base for the enemy. Additionally, the size of the map was reduced to be half the size of the full-map version. Although this version maintained the difficulty of the full-map version, it did not emphasize maintaining as much awareness and task switching as the full-map version (Glass, et al., 2013). The terrain and layout of the map differed for the half and full-map versions.

Glass, et al. (2013) further modified the gameplay of StarCraft in their study to encourage faster thinking. In StarCraft, when a player's assets become under siege a visual alert on the mini-map and an audio alert are presented to the player (refer to figure 2.2 of chapter two which includes the location of the mini-map in the graphical representation of the StarCraft user interface). In their study, this feature was disabled which compelled players to rely on memory to determine events that occurred on areas of the map that were not currently visible on screen (Glass, et al., 2013).

Albeit the results of the study conducted by Glass, et al. (2013) suggest that the full-map version of StarCraft is better for improving task switching performance than the half-map version, the construction of outposts in multiple areas of the map that contain rich resource nodes is an action players will always perform as they improve in the game.

In StarCraft, a key strategy to winning is to expand and build bases at rich research nodes or to deny the opponent's expansions to develop an economical advantage. Experienced players will attempt to establish second bases or third bases in the early stages of a skirmish. Early expansion is a highly recommended manoeuvre and a fundamental strategy for developing an economical advantage over an opponent.

For example the Zerg almost always establish a second base at rich resource nodes during the early stages of a game. Their racial abilities and characteristics facilitate faster and cheaper expansion than the Terran and Protoss. Therefore, this game setting was not altered and was kept at the game's default (beginning the game with one base) for this study.

The selection of the map which varied in size, terrain and total resources was left to the players' discretion in this study. This decision was taken because the half-map and full-map version approach implemented by Glass, et al. (2013) were not followed.

Participants in the experimental group were instructed to play all types of scenarios that StarCraft offers. These scenarios included a one-versus-one skirmish against a computer-controlled opponent, a one-versus-one skirmish against another player or the story mode of the game. This approach was adopted because the story mode of the game serves as a tutorial for new players, introducing new units with each mission and explaining their purpose and roles they fulfil.

Moreover, this approach was intended to keep players interested in the game throughout the training schedule as the game's plot was revealed. Keeping players interested in StarCraft was pivotal to the success of data collection as subjects participated in this study for no monetary or any other gains. Additionally, this assisted in mitigating the participant attrition/mortality threat to internal validity. The decision not to alter the visual and audio alerts in StarCraft for this study was appropriate because only one group was formed that played StarCraft, making it difficult to measure the effects of altered game states.

In many RTS video games various races or nations are playable which have distinct strengths and weakness. The next section examines the races that players were allowed to use in this study.

- **Race Selection**

The race selection rules enforced in the studies discussed in the literature will be reviewed followed by how this study approached race selection options in StarCraft.

Boot, et al. (2008) allowed the RTS video game (RoN) to randomly assign nations to the player and computer-controlled opponents in each scenario. Like StarCraft, each unique nation inherits a set of strengths and weaknesses. Similarly, Basak, et al. (2008) varied the participants and computer-controlled nationalities in RoN throughout the training program. Participants in the study by Glass, et al. (2013), always played against a computer-controlled Terran opponent. It is unknown whether players were compelled to play this race or given freedom of choice to select other races.

Subjects were allowed to choose any race that suited their tactics, strategies and preferences within a multiplayer game or against a computer-controlled opponent. The computer-controlled race was always set to random in one-versus-one scenarios. As mentioned in the previous sub-section, keeping players interested in StarCraft was pivotal to the success of data collection. Compelling participants into playing with a particular race which did not suit their preferences may have hampered their completion of the training regime. Furthermore, the effects of playing with different races on task switching performance were not investigated which falls outside the scope of this study. Finally, the story mode of StarCraft which players were allowed to play, involved playing with all three races at different stages of the campaign, beginning with the Terran.

The difficulty setting which is the final aspect of the game setup will be delineated in the next sub-section as planned.

- **Difficulty**

This sub-section begins by examining how authors of other studies on video game training define difficulty. Thereafter, the configuration of this setting in their RTS video game training programs will be looked at. Finally, the difficulty settings of StarCraft enforced in this study will be disclosed.

Boot, et al. (2008) progressively increased the difficulty of the scenarios in RoN that subjects were made to play. The first few scenarios were played against one computer-controlled enemy while subsequent scenarios involved two (Boot, et al., 2008). Basak, et al. (2008) had respondents begin RoN scenarios on the difficulty set to "easiest" which was altered following a set schedule. Difficulty was defined as the total amount of resources available to the opponent by Glass, et al. (2013) who utilized StarCraft in the training program. This amount ranged across fifteen levels and was adjusted based on the players previous match result (Glass, et al., 2013).

In StarCraft, there is no way that determines the skill of computer-controlled enemies. This study did not define difficulty as the total resources available on a map. The total amount of resources available on the map does not necessarily increase the difficulty because playing a game with fewer resources to harvest would only cause players' to adjust their tactics and strategies to cope under this economical restraint. Hence the resources available to all players in one-versus-one scenarios only changed according to the map that was selected.

As mentioned in section 3.6, respondents participated in this study for no monetary gains or other benefits. Extreme difficulty settings may have discouraged players from completing their training programs. Moreover, players were not expected to drastically improve their skill after twenty hours of StarCraft practice. Thus, the number of opponents subjects played against in custom games always remained one.

Finally, there are no settings in StarCraft to adjust the difficulty of the campaign/story mode. The story mode of the game was incorporated into the training schedule to assist in introducing the various units of the races and the functions they serve which eased the learning curve of the video game.

Other studies on video games, cognitive flexibility and executive functions have always examined if video game practice leads to improvement in the game before evaluating performance on post-training tests that measure executive functions. In this study, game performance was measured to ascertain if an improvement in a RTS video game translated into enhanced task switching abilities. The next section justifies how game performance was measured by the studies in the literature followed by how this study measured game performance.

3.9.2 Game Performance

In the final training session of the study conducted by Boot, et al. (2008), groups replayed a RoN scenario completed at the beginning of the training schedule. The statistics (made up of “wonders”, territory, player speed and various others), total scores and victory or defeat from these two scenarios were compared to determine if players improved in the game and their degree of improvement (Boot, et al., 2008).

Basak, et al. (2008) followed a similar approach, comparing scores and victory or defeat from the pre and post-training scenarios. However, they also analysed player speed (one of the many statistics that form part of the total score in RoN) from the pre and post-training scenarios. Player speed in RoN is calculated by the number of times a player clicked the mouse or used a hotkey (keyboard shortcut) during a skirmish (Basak, et al., 2008).

Glass, et al. (2013) measured respondents’ performance in StarCraft in several ways. Numerous pieces of data were collected from each game played which included the number of key presses during the game, the winner of the skirmish and the cumulative resources collected. Additionally, game state features were recorded which included data such as: if a unit was being attacked, patrolling/not patrolling, idle/not idle and proportion of health remaining amongst various other characteristics. This information was constantly being recorded (every two hundred and fifty milliseconds) for every unit that existed in a skirmish.

This collected data facilitated advanced analysis, enabling the authors to construct a selection/feature analysis. The model empowered the authors to pinpoint which features in the near past drove user actions in the present. Thus the authors were able to determine the extent of task switching performed by participants in StarCraft via the number of game features they interacted with.

Game performance in this study was measured by instructing participants in the experimental group to play a one-versus-one skirmish against a computer-controlled opponent before undergoing twenty hours of StarCraft training. Their total score, duration of the game and win or loss were recorded. At the end of the training program, participants replayed this scenario and the same statistics were recorded. The data from these two scenarios were compared to measure improvement in game performance.

A few issues with this game performance measurement method exist which will be now be addressed. The first being, a decrease in scores from the pre to post-training scenarios does not necessarily imply that players’ performances in the game have deteriorated. Boot, et al. (2008) found that scores decreased from the pre to post-training scenarios. This occurred because the scenario’s duration decreased for participants who achieved victory. This translated into reduced time in which to accumulate a higher total score. Hence in this study, the duration of the scenarios were examined in conjunction with the total scores.

The second issue that arises from score comparison is player speed or the number of key presses during a game. In RTS video games it is a common practice for players to click or use hotkeys multiple times to issue the same command (resulting in subsequent clicks or button presses after the first redundant) to ensure the correct input or command is registered by the user interface making this component of player score an inaccurate measure of the degree of task switching that occurs within the game. Therefore, data related to the number of key presses and player speed and were not recorded.

The game state feature analysis tools created by Glass, et al. (2013) would have revealed the extent to which participants in the experimental group switched between tasks in StarCraft which would have assisted in ascertaining whether greater task switching within a RTS video game translated into improved performance in the task switching test measures. These tools could not be acquired and the lack of this analysis remains a limitation of this study.

Having explored the research instruments in details, the ethical requirements for this study will now be examined. When conducting any type of research, ethical issues exist which must be taken into consideration. The following section will describe the ethical boundaries for this study and how this study kept within these boundaries throughout the research process.

3.10 Ethical Requirements

Consent was required from each participant before including them in this study. The second page of the questionnaire requested participants’ consent and included an area for their signatures and date. This consent page meant that all respondents agreed that their completed questionnaires, their participation in the RTS video training (experimental group members only) and the results from the task switching test measures were to be used for research purposes only. This consent page was signed off by all subjects who participated in this study. These signatures were obligatory which formed part of the ethical requirements. Furthermore, only subjects who were eighteen and over were allowed to participate.

No personal information was requested from respondents and their answers to the questionnaire remained anonymous at all times. Their names do not appear in print in any area throughout this study. A copy of the questionnaire was sent to the Ethical Requirements Committee at the University of KwaZulu-Natal (UKZN) for approval. The committee approved this application (see appendix U) and provided a gatekeeper's letter (see appendix T) which granted permission to include students at the UKZN campus in this study.

Having discussed the ethical requirements of this study, the next section declares and describes the various limitations of this study,

3.11 Limitations of this study

In this section the limitations of the sampling size and method, threats to internal and external validity, lack of game state feature analysis and the disadvantage of usage in other video game genres will be specified.

The sample size recruited for this study may be inadequate to generalize across the entire non-playing RTS VGP population which remains unknown. Additionally, the snowball sampling method employed is subject to biases and remains a limitation.

Demand characteristics, experimenter effects and the effects of testing remain threats to internal validity and are limitations of the data collected. Furthermore, any compensatory rivalry or resentful demoralization that could have occurred remains as threats to the internal validity of the data generated through the research instruments. Moreover, the interaction and selection of testing/treatment, and demand characteristics also remain threats to the external validity of the collected data which may make it difficult to generalize the findings of this study. Nevertheless, the mitigation methods utilized to provide consistency to the reliability, internal and external validity have been addressed in the appropriate sections (see section 3.4.6 for reliability and validity).

Participants usage in other video game genres throughout the duration of the study were unaccounted for which may have impacted on their performances in the task switching test measures.

Finally, game state feature analysis of StarCraft which was conducted by Glass, et al. (2013) would have revealed the extent to which participants in the experimental group switched between tasks in the RTS video game. The data generated by this tool could then have been compared against the performances in the task switching test batteries to ascertain if greater task switching within the RTS video game translated into improved performance in the task switching test measures. The game state feature analysis tools for StarCraft could not be acquired for this study and the lack of this analysis for game performance remains a limitation.

The next section summarizes this chapter by recapping the purpose of this chapter and the issues discussed to fulfil this chapter's goal.

3.12 Conclusion

The purpose of this chapter was to present the research methods, techniques and instruments that have been chosen for this study in detail and justify their use. The chapter began by revisiting the statement of purpose and research questions this study seeks to answer followed by a discussion on the research decisions taken in this study according to the research onion derived by Saunders, et al. (2009). The procedure followed for data collection was illustrated and explained followed by a detailed description of each research instrument and how they were implemented in this study. Finally, the ethical issues and limitations of this study were addressed. The next chapter will present the findings of the study followed by a detailed analysis of these findings.

Chapter 4 - Findings and Analysis

4.1 Introduction

The goal of this chapter is to answer the research questions to fulfil the purpose of this research. This will be done by presenting the research questions and answering them. To answer the research questions, the important findings gathered from the research instruments will be presented. These findings will then be explained followed by the analysis and implications of these findings.

This chapter is divided into four sections. The first segment addresses the reliability and validity of the data collected through the research instruments. The second section discloses the characteristics of the sample population acquired for this study. The third segment of the chapter presents the research questions. Each research question presented in this chapter is followed by the applicable findings and discussion to provide answers for them. The final part of this chapter provides support for the null hypothesis of this study.

A summary of all statistical tests performed for this study can be viewed in appendix E. This chapter begins by addressing the reliability and validity of the data generated from the questionnaire research instrument of this study.

4.2 Reliability

The statistical tests for the reliability of the data collected in this study are presented sequentially as per the questionnaire research instrument. Table 4.1 below reflects the results of the reliability analysis (derived from the results of the reliability statistical tests which can be viewed in the tables under section F1, F2, F3 and F4 of appendix F).

Table 4.1 - Cronbach's Alpha

Section	Cronbach's Alpha	Number of items
Video game expertise for each video game genre	0.547	10
Section C1	0.675	6
Section C2	0.811	6
Section C3	0.813	10

The outcome of the Cronbach's Alpha tests reflects that the questionnaire has a high degree of reliability and that the items in the questionnaire have a strong level of inter-item consistency (Cooper & Schindler, 2011; Mouton & Babbie, 2001).

4.3 Validity

To test the validity of the data generated, a factor analysis was conducted as a data reduction technique to summarise the item loadings under factors summarising the questionnaire research instrument. The purpose of factor analysis was to discover simple patterns in the relationships amongst the variables. The results of a Kaiser-Meyer-Olkin Measure of Sampling Adequacy test are presented in table 4.2 below (derived from the results of the validity statistical tests which can be viewed in the tables under section G1. G2, G3 and G4 in appendix G)

Table 4.2 - KMO test

Section	Kaiser-Meyer-Olkin Measure of Sampling Adequacy
Video game expertise for each video game genre	0.512
Section C1	0.587
Section C2	0.796
Section C3	0.723

Table 4.2 above reveals that the Kaiser-Meyer-Olkin Measure of Sampling Adequacy was > 0.5 for all four sections, thereby revealing that the sample was adequate, and a factor analysis appropriate, thereby producing reliable results, as correlations are relatively compact.

In the previous sections the statistical tests that assess the reliability and validity of the data generated through the questionnaire were presented. The results indicated that the data generated from the questionnaire research instrument was both reliable and valid. The next part of this chapter discloses the characteristics of the sample population acquired for this study as delineated earlier.

4.4 Sample population of this study

As discussed in section 3.5 of chapter three, the minimum size of the sample used in this study was thirty two and any suitable respondents that pushed the sample size beyond the minimum were permitted to participate. Thirty four subjects were acquired and participated in this study which comprised twenty eight males and six females. Males and females were randomly assigned to the control or experimental group (as described in the participation selection sub-section of reliability in section 3.4.6 of chapter three) which consisted of fourteen males and six females each. The mean age of the control and experimental groups were 24.17 and 23.41 respectively to facilitate the comparison of this study's results to the results of other studies discussed in the literature (as indicated in section 3.5 of chapter three). The sample population and group characteristics of this study are listed in table 4.3 that follows.

Table 4.3 - Sample population of this study

Number of groups	Group characteristics				
	Name	Size			Mean age
		Gender		Total	
		Males	Females		
2	Control	14	3	17	24.17
	Experimental	14	3	17	23.41
	Total	28	6	34	23.80

In this section, the characteristics of the sample population of this study were disclosed. The next section of this chapter will discuss and answer the first research question as outlined.

4.5 Research question 1

What impact do RTS video games have on non-playing RTS VGPs' task switching performance?

As stated in section 3.2.1 of chapter three, the two factors that affect task switching performance are the reaction times on switch trials (switch costs) and accuracy (errors) on all trials. These elements will be analysed to discover the impact RTS video games have (positive/negative/no impact) on task switching ability. The hypotheses for this study are listed in table 4.4 below.

Table 4.4 - Hypotheses

Hypothesis	Statement
Null hypothesis (H0)	RTS video games have no impact on non-playing RTS VGPs' task switching performance.
Alternative hypothesis (H1)	RTS video games positively influence non-playing RTS VGPs' task switching performance
Alternative hypothesis (H2)	RTS video games negatively influence non-playing RTS VGPs' task switching performance

These hypotheses will be tested through statistical tests that reveal the impact RTS video games have on non-playing RTS VGPs' task switching performance. The results from the statistical tests will facilitate the acceptance or rejection of the null and alternative hypotheses.

4.5.1 Switch Costs

To determine the effect of RTS video games on switch costs, the switch costs from the pre and post training task switching test batteries will be compared between the experimental and control groups (a summary of all statistical tests performed for switch costs can be viewed in section H1 of appendix H). The switch costs for the experimental group will first be examined. A non-parametric Wilcoxon signed-rank test (p=0.025) (see tables in section H11 of appendix H) and a paired sample T test (p=0.046) (see tables in section H13 of appendix H) indicates a statistically significant difference between the mean pre-training switch costs and the mean post-training switch costs for the experimental group. Figure 4.1 below depicts the mean switch costs in milliseconds for the experimental group for the pre-training and post-training tests.

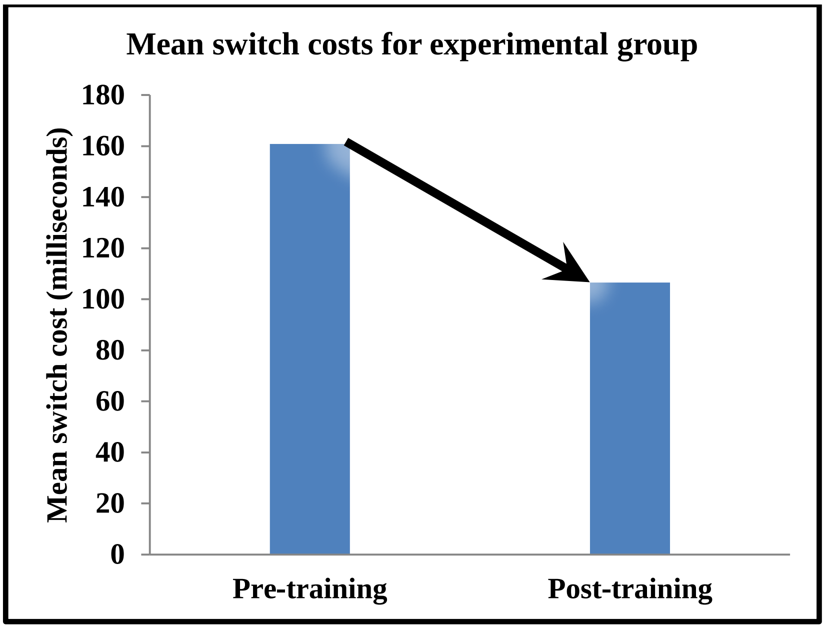


Figure 4.1 - Mean switch costs for experimental group

Figure 4.1 above illustrates a reduction in switch costs for subjects who trained in StarCraft for twenty hours. They reduced their switch costs from an average of 160.895 milliseconds in the pre-training task switching test to an average of 106.626 milliseconds in the post-training measures. The switch cost is calculated by measuring the difference in reaction times between switch and non-switch trials (as described in the literature review chapter). The outcome of this calculation results in smaller switch costs for populations with faster reflexes and quicker reaction times (Green, et al., 2012). To address this problem a proportional switch cost was calculated based on the study by Green, et al. (2012). The next section explains and explores the results of the proportional switch cost.

4.5.2 Proportional switch costs – experimental group

The proportional switch cost is calculated as the percentage increase in reaction times from non-switch trials to switch trials for each participant (Green, et al., 2012). This addresses the problem of individuals with naturally faster reaction times.

The pre and post-training proportional switch costs for the experimental group will first be inspected. Thereafter, the proportional switch costs for both groups will be compared (experimental vs. control) (a summary of all statistical tests performed for proportional switch costs can be viewed in section I1 of appendix I). The results of a non-parametric Wilcoxon signed-rank test reveal a statistically significant difference (p=0.035) between the mean proportional switch costs in the pre and post-training tests for the experimental group (see tables in section I11 of appendix I). A reduction in proportional switch costs for the experimental group can be viewed in figure 4.2 below.

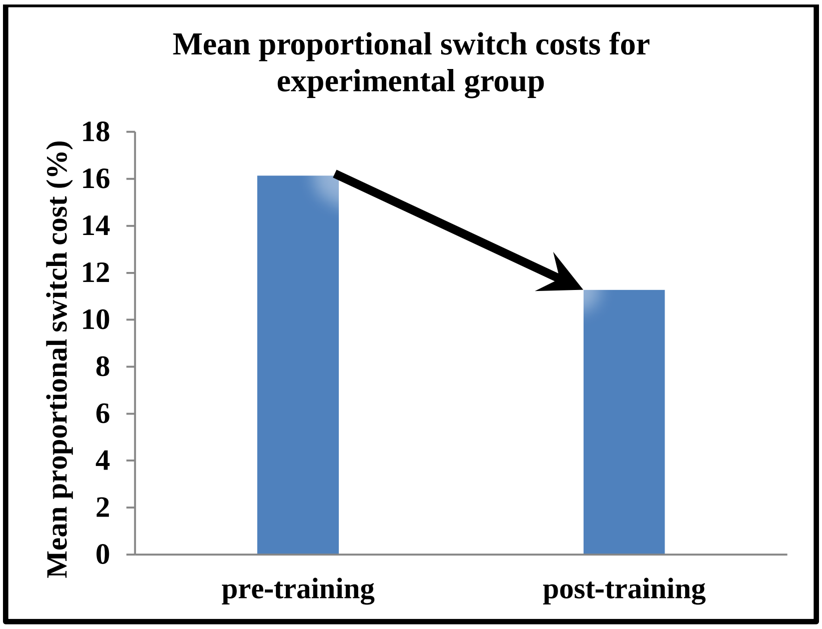


Figure 4.2 - Mean proportional switch costs for experimental group

The results of the statistical tests (see tables in section I11 of appendix I) and figure 4.2 above indicate that the experimental group decreased their proportional switch costs after twenty hours of RTS video game training. This suggests that RTS video games improve task switching performance. However, as discussed in section 3.4.3 of chapter three, the dependant variable (task switching performance) is measured after the intervention of the independent variable (RTS video game StarCraft) for both the control and experimental group (Saunders, et al., 2009) in studies implementing experimental strategies. Thereafter, the difference of the dependant variable between the two groups can be attributed to the intervention tool (Saunders, et al., 2009).

Having looked at the pre and post-training proportional switch costs for the experimental group, the pre and post-training proportional switch costs between the two groups will be compared (experimental vs. control), as outlined in the previous section.

4.5.3 Proportional switch costs – control vs. experimental group

Various statistical tests were performed that examined the proportional switch costs between the control and experimental groups in the pre and post-training task switching test batteries (see section I1 and tables in section I11 and I12 of appendix I). The outcome of a non-parametric Mann-Whitney test revealed no statistically significant differences (p=0.418) between the mean proportional switch costs for the control and experimental group in the pre-training test (see tables in section I3 of appendix I). Additionally, no statistically significant differences were found (p=0.593) between the proportional switch cost means for these two groups in the post-training test (see tables in section I5 of appendix I). Figure 4.3 below illustrates the mean proportional switch costs for the experimental and control groups in the pre and post-training tests. Table 4.5 that follows lists the proportional switch cost percentages.

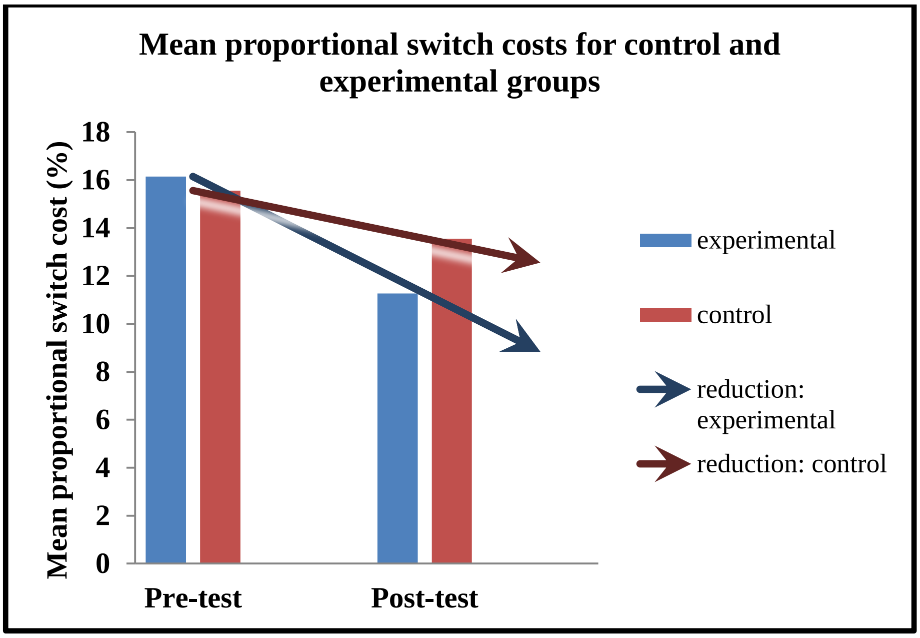


Figure 4.3 - Mean proportional switch costs for control and experimental groups

Table 4.5 - Proportional switch costs percentages

Sample	Pre-test proportional switch cost %	Post-test proportional switch cost %
Experimental	16.144	11.270
Control	15.559	13.557

Table 4.5 and figure 4.3 above depicts a reduction in proportional switch costs for both groups. Although, the experimental group reduced their proportional switch costs after twenty hours of RTS video game training, the difference in the reduction between the two groups was not great enough to be statistically significant. This result suggests that RTS video game training has no impact on non-playing RTS VGPs' task switching performance.

The next section addresses the error rates which form the second aspect of task switching performance as outlined in the beginning of this chapter.

4.5.4 Error rates

As described in section 4.5, accuracy was also taken into consideration when determining task switching performance. An individual could reduce their switch costs by forgoing accuracy on trials. No specific instructions were given to participants in this study that directed them to bias speed over accuracy or vice versa (justified in section 3.12 of chapter three). By examining the accuracy for all participants, the postulation that the reduction in switch costs is due to a speed/accuracy trade-off can be eliminated.

Three variables were associated with the accuracy measure, which are described in table 4.6 below.

Table 4.6 - Accuracy variables

Variable	Explanation
Task repeat errors	Total errors that a subject made on non-switch trials in the task switching test battery
Task switch errors	Total errors that subjects made on switch trials presented in the task switching test battery.
Net errors	Net errors = task repeat errors + take switch errors[15]

These variables were computed for each participant in the pre and post-training task switching test battery. Figure 4.4 below shows the net errors for the control and experimental groups in the pre and post-training task switching test batteries (section G1 of appendix G provides a summary of all statistical tests performed on net errors).

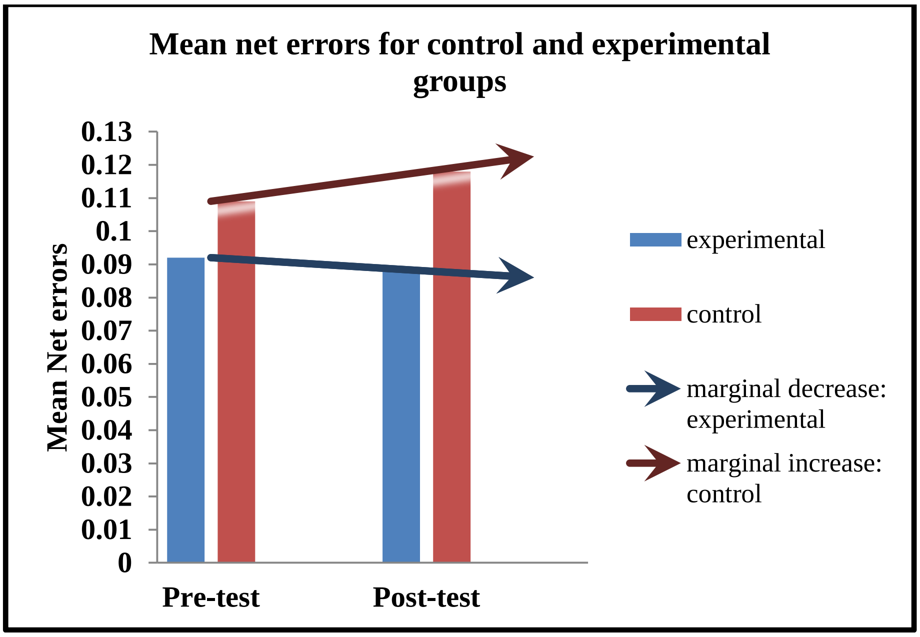


Figure 4.4 - Mean net errors for control and experimental groups

As described in section 3.8.4 of chapter three, the task switching test battery consisted of one hundred trials. For net errors, a number of 0.01 would indicate that one error was made by a test subject on all one hundred trials. Figure 4.4 illustrates that mean net errors dropped from just over nine errors to slightly fewer than nine errors for the experimental group (see table J10 in appendix J). For the control group, mean net errors increased from just fewer than eleven errors to just fewer than twelve errors in the post-test (see table J8 in appendix J).

[15] For a detailed explanation of switch and non-switch trials refer to section 2.12 and 2.12.1 of chapter two.

These changes were almost negligible and the results of non-parametric Mann-Whitney tests revealed no statistically significant differences for net errors between the two groups in the pre (p=0.389) (see tables in section J3 of appendix J) and post-training tests (p=0.427) (see tables in section J5 of appendix J). The results of additional statistical tests suggest that the small change in net errors for both groups were not great enough to be statistically significant (refer to section J12 of appendix J for further statistical tests performed on net errors). Hence the reduction in proportional switch costs exhibited by participants in this study cannot be attributed to any speed or accuracy trade-offs. Furthermore, these results suggest that accuracy had no influence on subjects' task switching performance in this study.

In the study conducted by Glass, et al. (2013), they combined both the response times and accuracy of their task switching test to arrive at a single measure for task switching performance. This study also combined the switch costs and accuracy data into a single measure. This measure for participants in the control and experimental group were then compared. The results of these statistical tests revealed no statistically significant results (see tables in appendix K for statistical analysis that test switch costs and net errors as a single measure). Additional analysis of the reaction times between participants of the control and experimental groups using this single measure variable were also performed, which yielded no statistically significant results (see tables in appendix L).

Although subjects in the experimental group improved their task switching ability after twenty hours of StarCraft practice (over a period of time), the final outcome from the proportional switch cost and net error statistical tests prevented the rejection of the null hypothesis. Hence, the alternative hypotheses were rejected and the null hypothesis was accepted. The statuses of these hypotheses are presented in table 4.7 below.

Table 4.7 - Statuses of hypotheses

Hypothesis	Statement	Status
Null hypothesis (H0)	RTS video games have no impact on non-playing RTS VGPs' task switching performance	Accepted
Alternative hypothesis (H1)	RTS video games positively influence non-playing RTS VGPs' task switching performance	Rejected
Alternative hypothesis (H2)	RTS video games negatively influence non-playing RTS VGPs' task switching performance	Rejected

Table 4.8 that follows, lists the video game training studies discussed throughout this dissertation, their findings and how the outcome of this study compares to them.

Table 4.8 - State of the video game training literature and this study

Study	Population Trained	Games Used	Outcome
Basak, et al. (2008)	nVGPs	RoN	Video game training has a beneficial effect on task switching ability (Basak, et al., 2008).
Green, et al. (2012) (Experiment four)	nVGPs	UT 2004 CoD 2 The Sims 2	Marginally significant positive effect on task switching performance (Green, et al., 2012).
Glass, et al. (2013)	nVGPs	StarCraft	RTS video game settings that promote rapid assessment and coordination across multiple sources of information enhances cognitive flexibility (Glass, et al., 2013).
Boot, et al. (2008)	nVGPs	MoH Tetris RoN	No evidence that suggests video game practice improves task switching performance (Boot, et al., 2008)
This study	**Non-playing RTS VGPs**	**StarCraft**	**RTS video games do not improve task switching abilities.**

The acceptance of the null hypothesis in this study corresponds to the deductions derived by Boot, et al. (2008), who found no correlation between video game practice and executive control.

Having established that RTS video games have no impact on non-playing RTS VGPs' task switching performance the possible reasons for this occurrence in the context of this study will be explored in the next research question.

4.6 Research question 2

Why do RTS video games impact task switching performance in the way they do?

As outlined in section 3.2.2 of chapter three, this question will explore the possible reasons as to why the observed effect that RTS video games (no effect) have on non-playing RTS VGPs' task switching performance is occurring. This section will begin by addressing the methodological approach utilized in this study that may explain why no impact on task switching ability was observed. Thereafter the characteristics of sample population gathered for this study will be examined, to identify additional reasons that may explain the ineffectiveness of RTS video games as an intervention tool for improving task switching ability.

As discussed in section 4.5.3 earlier, both the control and experimental groups reduced their proportional switch costs in the post-training task switching test measures. However, the difference in improvement between the two groups was not great enough to reject the null hypothesis (refer to figure 4.3 and section 4.5.3 for a more detailed explanation). Nevertheless, the methodological approach and characteristics of the sample population that may explain the improvement noted for experimental group members will also be explored in their respective sections.

4.6.1 Methodological

The possible explanations arising from the methodological approach of this study will be explored in this section to explain the findings of this study. These include: game performance, story mode of StarCraft, game settings, training schedule, task-specific learning and interference from other video gaming activity.

- **Game performance**

This study followed the game performance analysis methods of the studies by Boot, et al. (2008) and Basak, et al. (2008) (see section 3.9.2 of chapter three for their procedures on game performance analysis and justification for utilizing their approach). For the experimental group, performance in StarCraft was measured in a one-versus-one scenario against a computer-controlled opponent as outlined in section 3.9.2 of chapter three. This one-versus-one skirmish was played by participants of the experimental group before beginning the training schedule. The same scenario was played once more after having completed twenty hours of StarCraft training. Figure 4.5 below lists the win/loss percentage for subjects in the experimental group in the pre and post-training StarCraft scenarios (see section O1 in appendix O for descriptive statistics on the mean win/loss ratios in the pre and post-training scenarios).

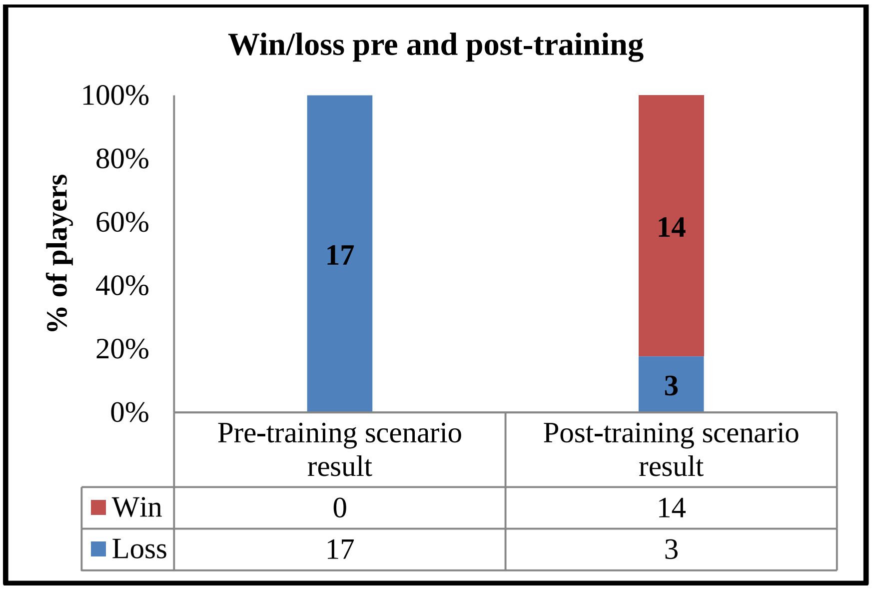


Figure 4.5 - Win/loss percentages pre and post-training

No players achieved victory in the pre-training one-versus-one scenario. After twenty hours of training, 82% of players achieved victory when the same scenario was replayed. Furthermore the results of a Wilcoxon signed-rank test ($p<0.005$) uncovers a statistically significant difference between the pre and post-training scenario results (see table O2 of appendix O). These results suggest that players improved in StarCraft after twenty hours of practice. Figure 4.6 below illustrates the mean total scores in the game in the pre-training scenario and post-training scenario (see section O1 in appendix O for the descriptive statistics on the mean total scores in the pre and post-training scenarios).

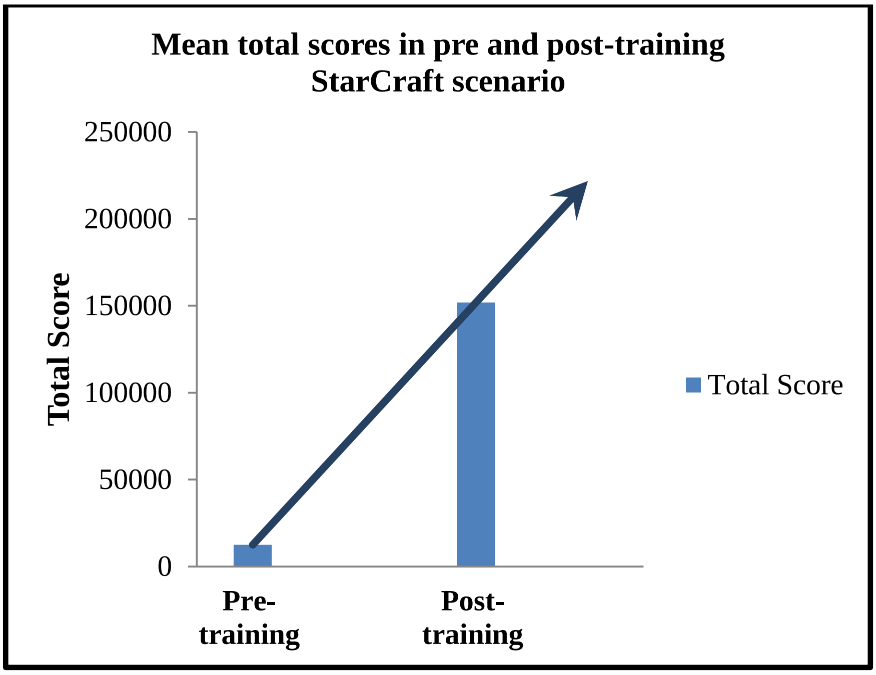


Figure 4.6 - Mean total scores pre and post-training

In the pre-training scenario the mean score of participants in the experimental group was approximately twelve thousand. After twenty hours of training in StarCraft, subjects increased their total scores when replaying the scenario resulting in a mean total score of roughly one hundred and fifty thousand. The result of a Wilcoxon signed-rank test ($p<0.005$) confirms a statistically significant difference between the pre and post-training mean scores (see table O2 of appendix O). These figures indicate that players were able to gather more resources, build larger armies and destroy more assets belonging to their opponent.

Figure 4.7 that follows depicts the mean duration of the pre and post-training StarCraft scenarios for experimental group subjects (see section O1 in appendix O for the descriptive statistics on the mean total scores in the pre and post-training scenarios).

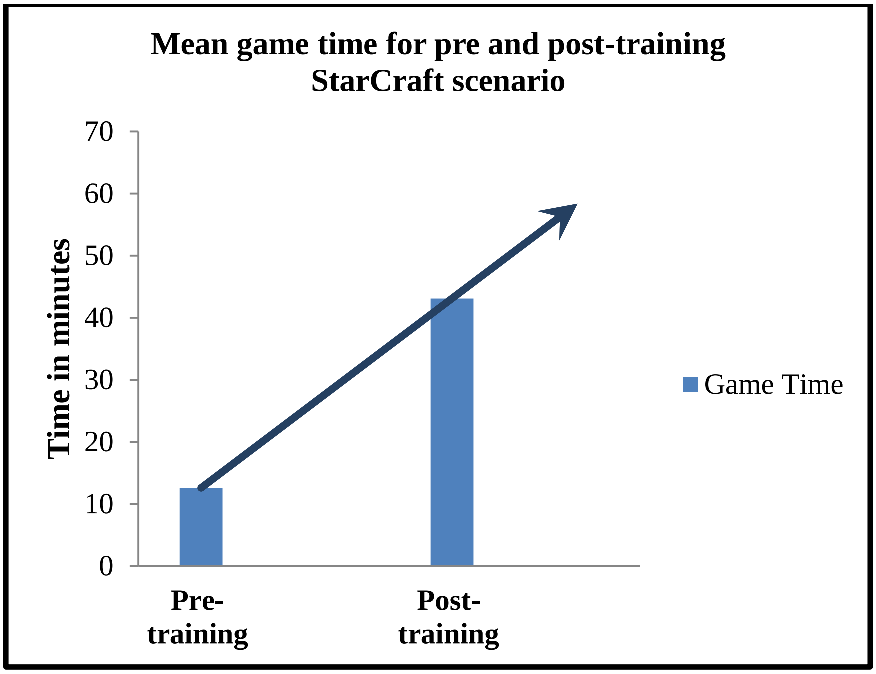


Figure 4.7 - Mean game time pre and post-training

In the pre-training scenario, the mean duration of the skirmish lasted approximately thirteen minutes. The mean time of this scenario lasted approximately forty three minutes when replayed after twenty hours of StarCraft practice. This difference is confirmed statistically in the results of a Wilcoxon signed-rank test ($p<0.005$) (see table O2 of appendix O). This statistically significant improvement indicates that players were able to survive for significantly longer periods of time, resulting in longer skirmishes and higher scores.

The triad of results (win/loss, total scores and game time) reveal that players showed an improvement in their StarCraft performance after twenty hours of training. This finding is consistent with the findings of all four video game training discussed in the literature [Boot, et al. (2008), Basak, et al. (2008), Green, et al. (2012), Glass, et al. (2013)] who found that subjects improved in the games they played after training in them over a period of time. These results may explain the reduction in proportional switch costs of members from the experimental group. Furthermore, the game performance analysis may indicate that improvement in a RTS video game such as StarCraft translates into improved task switching abilities. However, there are no statistical significant results from the data in this study to support this hypothesis.

Additionally, the analysis methods for game performance adopted in this study did not provide any data for players' task switching within the StarCraft scenarios they played. As a result, no data exists from this study that would indicate how often and when players switched between performing various tasks within the scenarios they played. Additionally, judging the frequency of task switching within the game such as gathering and spending available resources, utilizing units abilities and performing military actions is not possible from analysing the game scores and duration of the StarCraft scenarios alone. The lack of advanced analysis that measure player's task switching within StarCraft scenarios remains as a limitation of this study and has been addressed in section 3.11 of chapter three.

The methodology implemented by Glass, et al. (2013) could be followed in future studies which is described in detail in section 2.13.4 of chapter two and section 3.9.2 of chapter three. Their methodology enabled the authors to construct models that pinpointed which game features in the near past drove user actions in the present and more importantly how much task switching was performed by players in each StarCraft scenario. This model, together with detailed in-game data could be used to determine if the task switching in StarCraft scenarios correlates with improved task switching performance.

Moreover, the collection of detailed in-game data and the model constructed by Glass, et al. (2013), could determine if the extent of task switching that players perform within StarCraft is proportional to any changes in their task switching performance after training for a predefined number of hours.

Players' improvements in StarCraft did not translate into statistically significant improvements in task switching ability in the findings of this study. The next two sections (story mode and game settings) explore the setup of StarCraft utilized in further detail. These game settings remain possible explanations as to why the improvement in StarCraft did not translate into statistically significant improved task switching abilities.

- **Story mode**

Participants in the experimental group were instructed to play all types of scenarios in StarCraft which included the story mode of the game (as described in section 3.9.1 of chapter three). This approach was used because the story mode of the game serves as a tutorial to new players, introducing new units with each mission and explaining their purpose and roles they fulfil. Furthermore, this approach was intended to keep players interested in the game throughout the training schedule as the game's plot was revealed. Keeping players interested was pivotal to the success of data collection as subjects participated in this study for no monetary or any other gains (as described in section 3.9.1 of chapter three).

With the story mode of StarCraft, various issues with computer-controlled opponents exist that are prominent when compared to the behaviour of computer-controlled opponents in one-versus-one scenarios. Blizzard Entertainment discusses these issues in detail which are indicated in table 4.9 that follows.

Table 4.9 - Issues with AI in story mode

Number	Behaviour of AI(Artificially Intelligent)/computer-controlled opponents in the story mode of StarCraft
1	The computer-controlled opponents expect to start with a town and do not build new structures. They will only rebuild specific important structures like barracks (Blizzard Entertainment, 2014).
2	The computer-controlled enemies do not make an effort to expand in order to gather from rich resource nodes. Furthermore, they will not attempt to control locations that provide strategic and tactical advantages (Blizzard Entertainment, 2014).
3	The behaviours of the computer-controlled opponents are programmed to build only a few units that are capable of gathering resources because they expect to start with a large pool of resources (Blizzard Entertainment, 2014).
4	The computer-controlled enemies do not attempt to prevent the player from expanding their base or taking control of strategically advantageous areas (such as locations with rich resource nodes). Instead they attack any opposing unit or structure they find (Blizzard Entertainment, 2014).
5	The behaviours of the computer-controlled opponents have been programmed to attack periodically with set army compositions which are scripted. These army compositions are always followed regardless of what the player builds. When the script reaches its end, it repeats a few army composition set groups (Blizzard Entertainment, 2014). These patterns are predictable, can be learned by the player and are easily countered by producing units that are effective against these army compositions.
6	The computer-controlled enemies do not attempt to kill the player quickly and outright. They are meant to be defeated by players without extreme difficulty and the design of their behaviours reflect this (Blizzard Entertainment, 2014).
7	The computer-controlled opponents are slow in responding to the player's attacks allowing the player to destroy units, structures and cause damage additional damage before encountering extreme retaliation. This is done to make the game more fun whilst giving the player a better chance of winning (Blizzard Entertainment, 2014).

The behaviour of the computer-controlled enemies in the story mode of the game that has been listed in table 4.9 above, suggest that constant switching between performing multiple tasks in the story mode of StarCraft is not required on an as a high level as the extent of task switching required when playing scenarios against a computer-controlled opponent in a one-versus-one scenario or against another player. The reduced difficulty and task switching demands may explain the inability of players to exhibit sufficient improvement in their task switching performance to reject the null hypothesis.

The decision to incorporate the story mode of StarCraft into the training schedule despite the flaws with the behaviours of computer-controlled opponents in the story mode of the game has been justified in this section and in section 3.9.1 of chapter three. Respondents reported playing the story mode of the game for significant portions of the training schedule. However, these numbers were not recorded and therefore could not be analysed in any way.

In future studies the story mode of StarCraft should be utilized as a tutorial to allow players to gain an understanding of the mechanics on all three races and the functions each unit in the game serves. However, the primary focus should remain on skirmishes against a computer-controlled opponent or another player. The story mode of the game can require a significant time to complete. Hence, a training regime which includes more practice hours that is run over a longer period of time can facilitate the completion of the story mode and leave players with adequate time to play skirmishes against computer-controlled opponents or other players.

- **Game Settings**

The decision not to change any of game's default settings were justified in section 3.9.1 in chapter three. However, the results of this study suggest that the recommendations made by Glass, et al. (2013) could be a possible explanation as to why players were not able to sufficiently improve their task switching performance to reject the null hypothesis.

The findings of this study support the claims made by Glass, et al. (2013) that RTS video games only improve cognitive flexibility in scenarios that promote task switching on a high scale across multiple information sources. The game's settings of StarCraft could be altered in future studies in a manner that demands players to rapidly switch between performing various tasks across numerous sources of information to enhance task switching abilities.

Glass, et al. (2013) provide a methodology for encouraging this quick task switching across multiple sources of information in StarCraft. Skirmishes against computer-controlled opponents or other players should begin with two friendly bases and two enemy bases in different locations of the game world from the beginning of the scenario. This results in multiple battles against both bases which promotes additional task switching and coordination of cognitive resources than the game's default settings (Glass, et al., 2013).

Furthermore, disabling the visual alerts on the mini-map (which are displayed on the mini-map when a player's assets become under siege) and the audio alerts encourage faster thinking because it compels players to rely on memory to determine events that occur on areas of the map that are not currently visible on screen (Glass, et al., 2013).

The next section analyses the training schedule implemented in this study as a possible reason for the inability of StarCraft to improve task switching abilities.

- **Training schedule**

Table 4.10 that follows lists the video game training studies and their training schedules. In addition, the training schedule implemented in this study is included.

Table 4.10 - Training schedule

Study	Number of hours trained	Duration of training schedule
Boot, et al. (2008)	Fifteen training sessions. Total practice time of twenty one and a half hours	Four to five weeks
Basak, et al. (2008)	Fifteen one and half hour training sessions resulting in twenty three and a half hours of total training time	Seven to eight weeks
Green, et al. (2012)	Fifty hours of video game training	Six to fourteen weeks
Glass, et al. (2013)	One hour per day. Total of forty hours of practice	Seven weeks
This study	Twenty hours of video game training	Four to six weeks

As indicated in section 3.6 of chapter three, twenty hours of total video game training time was implemented because subjects participated in this study for no monetary benefit or gain which made it difficult to incentivize them to participate for longer periods of time. Therefore, the lowest number of hours was used to train.

It is possible that twenty hours of total video game training time was not sufficient to depict any statistically significant changes in a group of non-playing RTS VGPs with an average of sixteen years of video game experience (see table M3 in appendix M for descriptive statistics on demographics). Ideally, the training regime implemented by Green, et al. (2012) (total of fifty hours of video game training) could be followed. Training over a considerably longer period of time may be necessary before any statistically significant changes can be observed in a sample which reports substantial prior video game usage and experience.

The issue of task-specific learning which Green, et al. (2012) has emphasized will be discussed in the following section as a possible reason arising from the methodological approach of this study that may explain the above finding (no impact of RTS video games on task switching performance).

- **Task-specific learning**

As stated in section 3.6 and 3.8.5 of chapter three, participants from both groups (control and experimental) undertook the same task switching test battery pre and post-training. Figure 4.8 that follows depicts the mean proportional switch costs for subjects in the control group in the pre and post-training tests.

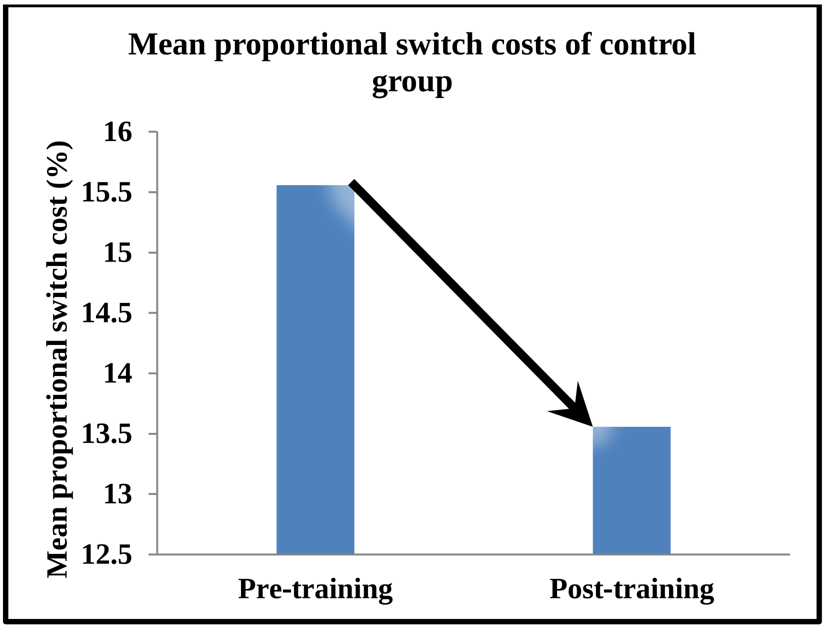


Figure 4.8 - Mean proportional switch costs of control group

These results indicate that participants in the control group also reduced their proportional switch costs when completing the task switching test battery for the second time. Exhibiting improved task switching performance on the second task switching test battery may indicate the issue of task-specific learning that Green, et al. (2012) has highlighted.

Green, et al. (2012) claim that repeated testing in a particular task switching test measure increases the likelihood of task-specific learning, meaning the best way for subjects to improve on a particular task is to repeatedly train on that very same task. Hence, subjects will improve their performances on task switching tests that they retake (as illustrated in figure 4.8). This reduces the effectiveness and accuracy of a task switching test battery as an instrument for measuring task switching abilities.

The reasons not to utilize different task switching tests in the pre and post-training task switching test batteries were addressed in section 3.4.6 of chapter three. Potentially, different task switching test batteries could be utilized in pre and post-training test measures to minimise task-specific learning from occurring.

The next section looks at other gaming activity that participants may have continued throughout the duration of the study as a possible reason for the main finding of this study (no impact of RTS video games on task switching performance).

- **Interference from other video gaming activity**

Throughout the duration of this study, all participants continued with their regular video gaming habits. It remains a possibility that their daily video game usage and exposure may have affected their performances in the task switching test batteries. However, no data was collected on participants' video gaming activity between the pre and post-training task switching test batteries.

To observe the effect of training in a specific video game genre on current VGPs, all participants could be instructed to stop all other video gaming activity for the duration of the training schedule. Alternatively, all their video gaming activities during the training program could be recorded. This may eliminate the problem of the effects of other video gaming activity on task switching abilities.

The next sub-section explores the casual video game genre that many participants reported playing.

- **Casual Games**

Roughly 21% (seven subjects) of the sample population reported playing the casual game Angry Birds developed by Rovio Entertainment (Rovio Entertainment, 2009). Approximately 26% (nine subjects) of the sample population reported playing the game Candy Crush Saga developed by King (King, 2012) (see tables in section N3 of appendix N for statistics). These games are mostly played on mobile devices (Dredge, 2013; Mazin, 2011). These types of games could have affected the results, as participants continued with their weekly video gaming habits in addition to StarCraft training throughout the training schedule.

Casual games do not require task switching on a high scale. However, they are mostly played on mobile devices (Mazin, 2011) which grant people the ability to play games whilst performing their daily routine tasks. Herein lies the challenge of having to switch between playing the game and performing other tasks of everyday life simultaneously. The widespread use of these types of games (Mazin, 2011) opens up avenues for future research which could assess the impact of casual games on task switching ability, particularly in real-world scenarios. This gap in the literature has been identified by researchers and has begun to receive attention which can be observed in recent studies (Baniqued, Kranz, et al., 2013; Baniqued, Lee, et al., 2013) .

As outlined in section 4.6, the next segment of this chapter will examine the sample population gathered for this study to identify additional reasons that may explain the ineffectiveness of RTS video games as a tool for improving task switching performance.

4.6.2 Sample population

Several aspects of the sample will be inspected closely namely: race, gender and prior video gaming experience. The age of the sample population was kept between twenty and twenty five to keep the results of this study comparable to others as indicated in section 3.5 of chapter three (see section M3 in appendix M for the mean age of 23.79). The next section examines at the racial distribution of the sample in this study

➢ **Racial Distribution**

Figure 4.9 below depicts the racial distribution of the sample that participated in this study (see table M2 in appendix M for statistics on race).

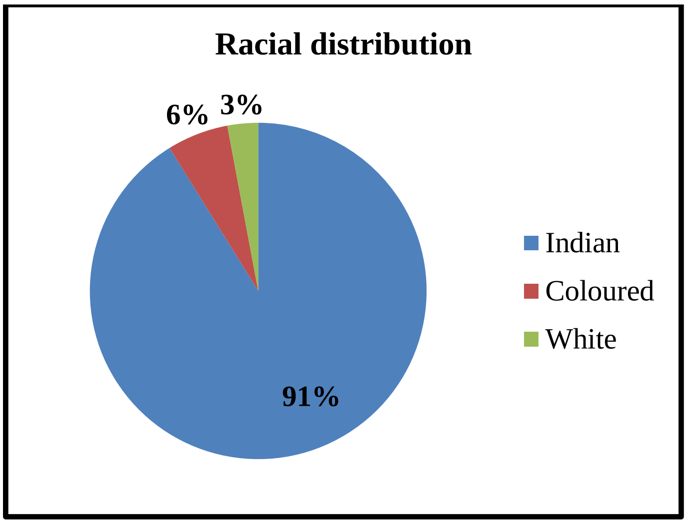


Figure 4.9 - Racial distribution

Figure 4.9 above illustrates that the majority of sample obtained in this study consisted of subjects who self-reported being Indians. It is possible that task switching may not be a trainable skill for participants who self-report being Indians and that RTS video games do not influence their task switching performances in any way.

Although self-reported Coloured subjects formed a small percentage of the sample population, the effect of RTS video games on their task switching ability will be examined next, to highlight the irregularities of this group.

➢ **Self-reported Coloured subjects**

Figure 4.10 that follows depicts the proportional switch costs for two participants who self-reported being Coloured, that formed part of the sample in this study. These two participants will be referred to subject X and subject Y. Subject X was a member of the control group whilst subject Y was a member of the experimental group.

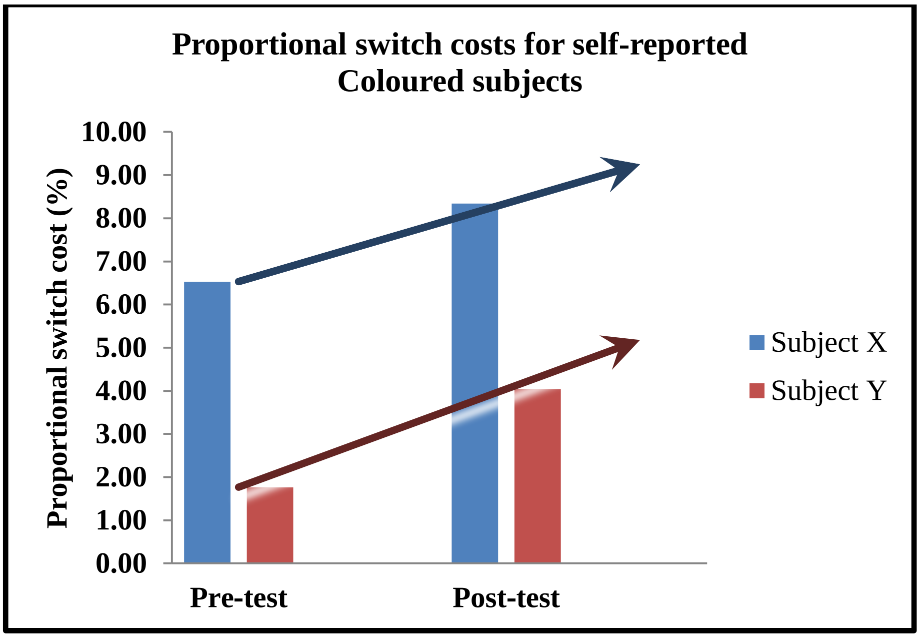


Figure 4.10 - Proportional switch costs for self-reported Coloured subjects

From figure 4.10 above, it can be noted that the proportional switch costs for both subject X and Y increased in the post-training tests suggesting that their task switching performance deteriorated. This result will be looked at in more detail by comparing their proportional switch costs to the sample average. Table 4.11 below depicts proportional switch costs in the pre and post-training tests for subjects X, Y and the sample average (see section P1 in appendix P for descriptive statistics on proportional switch costs).

Table 4.11 - Proportional switch costs for subject, X,Y and sample average

Sample	Pre-test proportional switch cost %	Post-test proportional switch cost %
Subject X	6.53	8.34
Subject Y	1.77	4.04
Sample average	15.851	12.413

It can be seen from table 4.11 above that although subjects X and Y's task switching performance deteriorated in the post-test task switching test battery, their proportional switch costs were still well below the sample average. This finding suggests that these two participants (who self-reported being Coloured) illustrated superior task switching skills than sample average.

To understand this phenomenon, their gaming habits will be examined to discover possible explanations for this occurrence. Figure 4.11 that follows, maps their video gaming expertise against the sample's average expertise for specific video game genres (see section P2 in appendix P for descriptive statistics on video gaming expertise). Figure 4.12 thereafter maps the hours per week that they play against the sample's average hours per week for these video game genres (see section P3 in appendix P for descriptive statistics on video game usage per week).

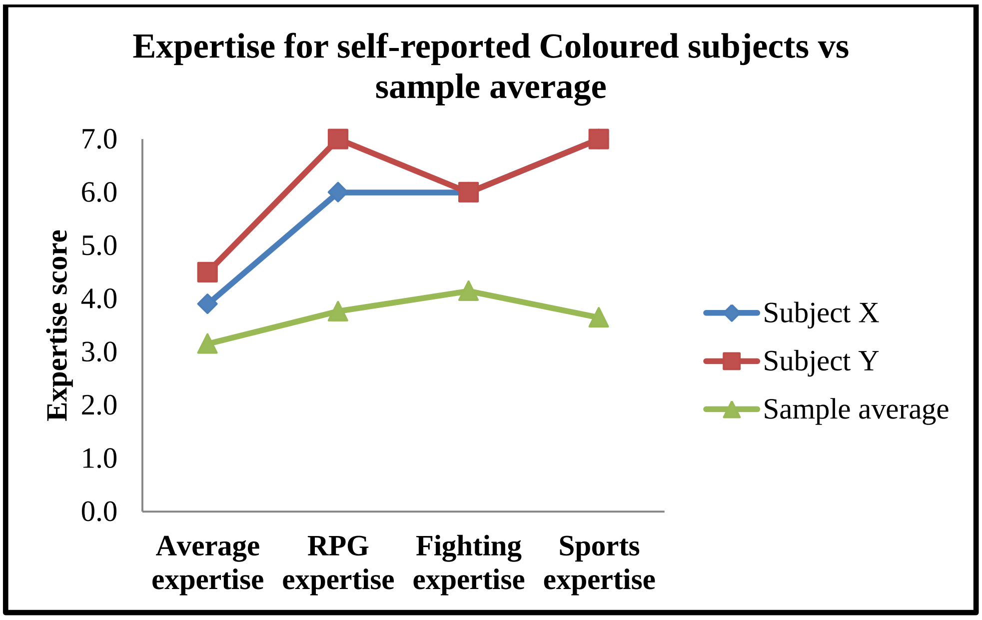


Figure 4.11 - Expertise for self-reported Coloureds vs. sample average

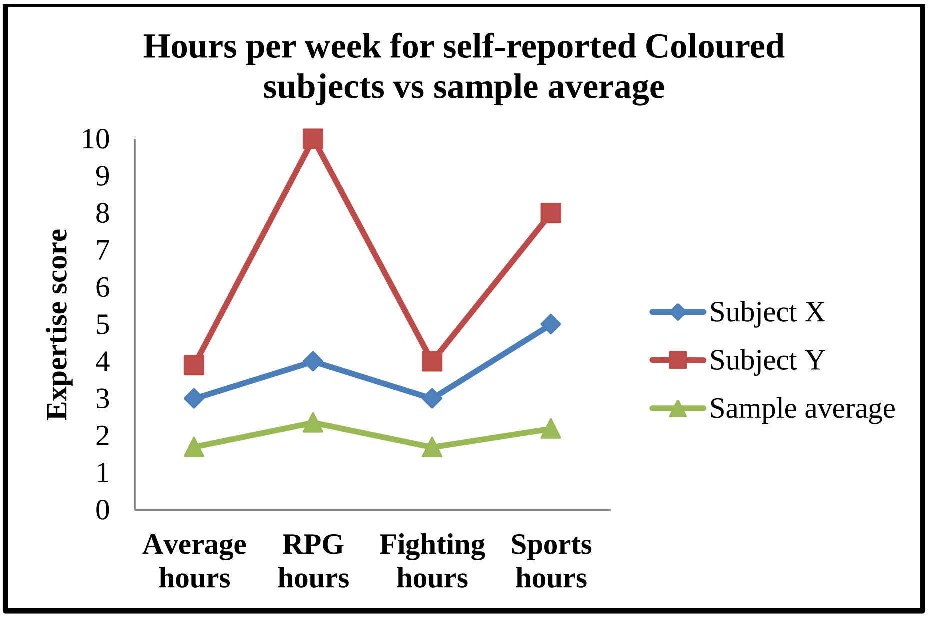


Figure 4.12 - Hourly usage for self-reported Coloureds vs. sample average

Figures 4.11 and 4.12 above indicate that the reported gaming expertise and hourly usage for the role-playing, fighting and sports video game genres for subjects X and Y were significantly higher than the sample's average. This may contribute to the ineffectiveness of RTS video games as a tool to further enhance their task switching abilities.

Role-playing video games are not known to contain activities that require task switching on a high scale. In fighting video games where players control one character, quicker reflexes enable the player to perform combination moves whilst being able to block and punish their opponent's manoeuvres and abilities. Fighting video games promote fast reaction times rather than efficient task switching (E. Adams, 2009).

Sports video games such as Ashes Cricket 2009 (Transmission Games, 2009) and the FIFA series (Electronic Arts Canada, 2013) (soccer) generally do not require task switching on a high scale. However, data relating to the type of sports video games that participants were exposed to were not recorded. It remains a possibility that certain types of sports video games that require constant task switching may have enhanced these two subjects' task switching performance to its maximum potential. An avenue for future research would be to investigate the various types of sports video games in the simulation video game genre and assess their effects on cognitive flexibility.

The next segment of this chapter inspects the gender aspect of the sample population from this study as planned.

- **Gender: females**

Six females volunteered to participate in this study. Three females were randomly assigned to the control group and the other three were assigned to the experimental group (as described in the participation selection sub-section of reliability in section 3.4.6 of chapter three). The reasons for including females in this study were given in section 3.5 of chapter three. Figure 4.13 below illustrates the gender distribution of the sample in this study (see section M1 in appendix M for statistics on gender).

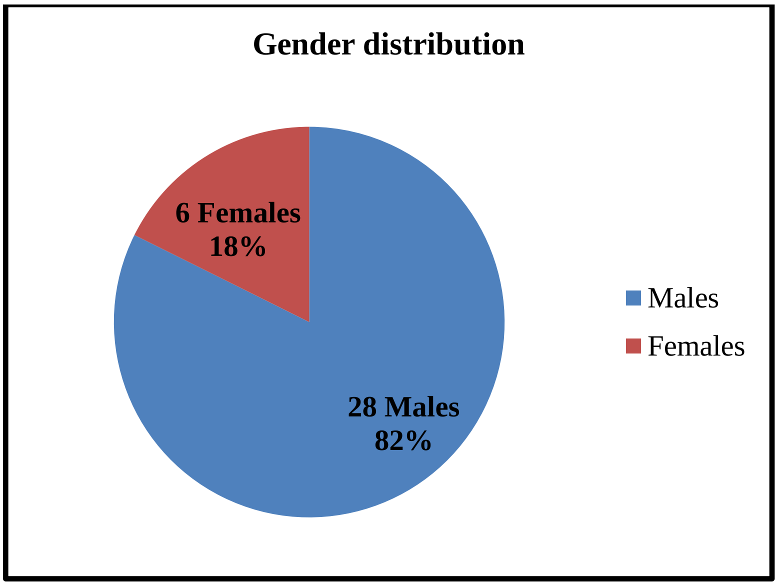


Figure 4.13 - Gender distribution

Various statistical tests were performed on the proportional switch costs for females which yielded no statistically significant results (a summary of all statistical tests performed for proportional switch costs for females can be viewed in section Q1 of appendix Q).

The outcome of a non-parametric Mann-Whitney test revealed no statistically significant differences (p=0.513) between the mean proportional switch costs for females of the control and experimental groups in the pre-training test (see tables in section Q3 of appendix Q). Additionally, no statistically significant differences were found (p=0.275) between the proportional switch cost means of females of both groups for the post-training test (see tables in section Q3 of appendix Q). Figure 4.14 below depicts the mean proportional switch costs from the pre and post-training task switching test batteries of all females who participated in this study. Table 4.12 that follows lists the proportional switch cost percentages.

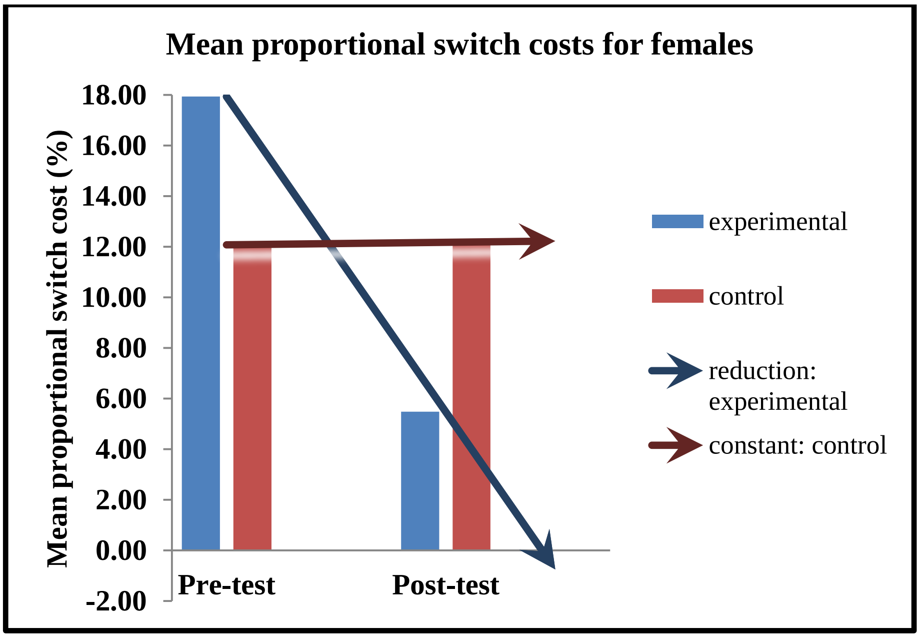


Figure 4.14 - Mean proportional switch costs for females

Table 4.12 - List of female proportional switch costs

Female sample	Pre-test proportional switch cost %	Post-test proportional switch cost %
Experimental	17.942	5.482
Control	12.076	12.176

Although not statistically significant, figure 4.14 and table 4.12 above confirm a reduction in proportional switch costs for females in the experimental group after training for twenty hours in StarCraft. This result suggests that training in a RTS video game for twenty hours had a positive influence on females’ task switching performance. The proportional switch costs of the females in the experimental group will now be compared to the proportional switch costs of the males in the experimental group to discover if any differences exist between the two.

- **Experimental group males vs. females**

A summary of all statistical tests which compare the proportional switch costs of males and females in the experimental group can be viewed in section R1 of appendix R. The result of a non-parametric Mann-Whitney test revealed no statistically significant differences (p=0.801) between the pre-training mean proportional switch costs of males and females in the experimental group (see tables in section R2 of appendix R). Furthermore, no statistically significant differences were found (p=0.313) between the post-training proportional switch cost means of males and females in the experimental group (see tables in section R2 of appendix R). However, the mean proportional switch costs will be illustrated to determine any trends that may be prominent. Figure 4.15 below illustrates the mean proportional switch costs (pre and post-training) of males against females in the experimental group. Table 4.13 that follows lists these proportional switch cost percentages.

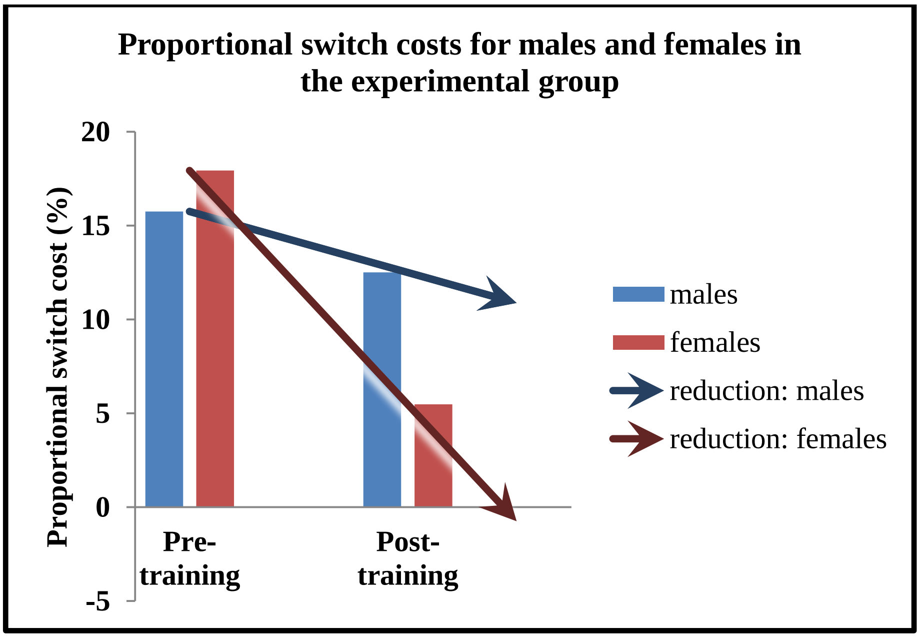


Figure 4.15 - Proportional switch costs for males and females in experimental group

Table 4.13 - List of males and females proportional switch costs in experimental group

Experimental group sample	Pre-training proportional switch cost %	Post-training proportional switch cost %
Males	15.759	12.510
Females	17.942	5.482

From figure 4.15 and table 4.13 above, it is evident that both genders reduced their proportional switch costs after training in StarCraft for twenty hours. However, a noticeable difference in the magnitude of this reduction can be observed from the trend lines in figure 4.15 and the statistics in table 4.13. These results hint at the possibility that RTS video games are better mechanisms for improving females' cognitive flexibility than males.

The improvement of females' task switching abilities documented in this study corresponds to the findings discovered by Basak, et al. (2008) and Glass, et al. (2013). They concluded that given the correct circumstances, training in a video game would improve cognitive flexibility. Table 4.14 that follows revisits the sample population of the studies who found video games to beneficial for cognitive flexibility. Figure 4.16 presented thereafter, illustrates the gender proportions of these samples.

Table 4.14 - Sample population of beneficial video game training studies

Study	Number of groups	Group characteristics						
		Name	Size			Mean age	Population	Video game used
			Gender		Total			
			Males	Females				
Basak, et al. (2008)	2	A	5	15	20	70.05	nVGPs	RoN
		B	5	15	20	69.10		None
Glass, et al. (2013)	3	A	0	26	26	20.3	nVGPS	StarCraft (SC-1 game setup)
		B	0	20	20	20.4		StarCraft (SC-2 game setup)
		C	0	26	26	19.9		None
Green, et al. (2012) – experiment four (training)	2	A	8	11	19	25.7	nVGPs	UT 2004 CoD 2
		B	4	13	17	24.7		The Sims 2

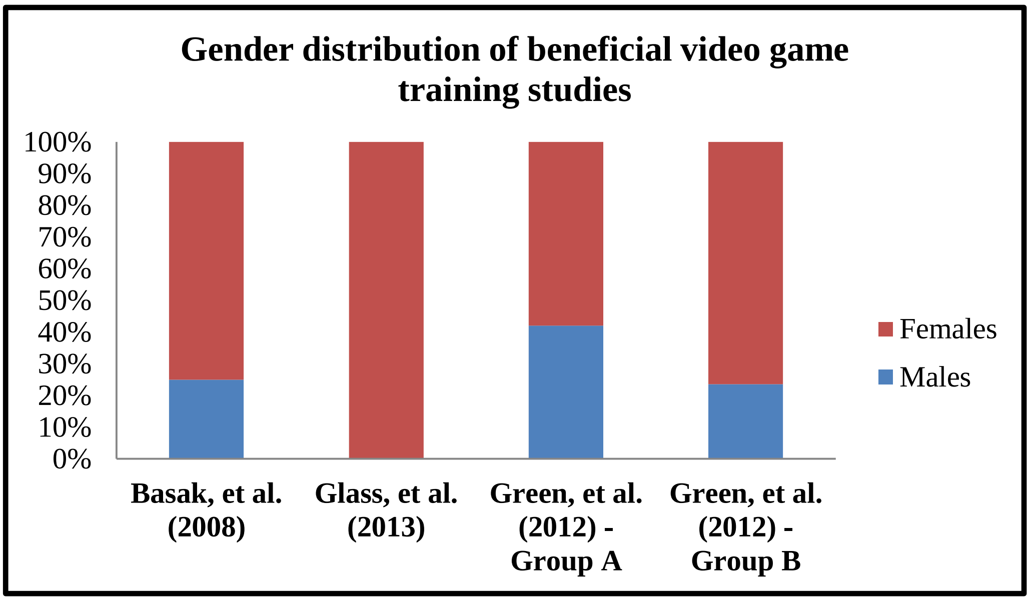


Figure 4.16 - Gender distribution of beneficial video game training studies

Table 4.14 and figure 4.16 above illustrate that their conclusions about the benefits of video games on cognitive flexibility were drawn from sample populations that were primarily female [with the exception of the study by Green, et al. (2012)].Therefore, their results and the findings of females in this study suggest that video games are especially effective mechanisms for improving females' cognitive flexibility.

As discussed in section 2.13.3, Green, et al. (2012) found only a marginal difference in task switching performance between the two groups that trained in video games in the fourth experiment of their study. One explanation they offered for this occurrence was that participants in group B also improved their task switching performance after playing the slower paced Life Simulation video game, The Sims 2, as opposed to the faster paced FPS video games (CoD 2 and UT 2004) that group A subjects played. This improvement by subjects of group B diminished the difference in task switching performance between the two groups.

Group B in their fourth experiment comprised 76% females (as shown in table 4.14 and figure 4.16) whereas group A had a smaller female presence (55% female) (as shown in table 4.14 and figure 4.16). This provides further evidence to suggest that video games are more effective tools for improving females' task switching performance than males.

There are various possibilities that could explain this phenomenon. One possibility is that females are better at absorbing the cognitive benefits of video games than males. Another possibility is that females may be better at transferring the cognitive benefits of video games into laboratory test settings than males. This occurrence introduces new avenues for future research that could investigate gender differences on the cognitive benefits of video games. Moreover, gender differences in the nature of these transfers into real-world environments can be examined.

Having addressed the gender aspect of the sample population, the next section explores the possible reasons as to why the null hypothesis accepted in this study is justified.

4.7 Support for null hypothesis acceptance

Although the potential explanations arising from the methodology were explored, the methodology followed in this study was acceptable and fully justified in chapter three. The next section looks at possible explanations which deems the acceptance of the null hypothesis of this study (RTS video games have no impact on non-playing RTS VGPs' task switching performance) appropriate.

The first section explores the video game experience of the sample of this study as a possible cause to explain why RTS video games do not alter current VGPs' task switching performance. The second section examines the theory that video games have no relationship with task switching abilities.

4.7.1 Prior video game experience

As part of identifying non-playing RTS VGPs, participants were questioned on their total video gaming experience (in years) and the total amount of time they spent playing video games every week for the past six months. These statistics are displayed in figure 4.17 that follows (see section M3 in appendix M for descriptive statistics on video game experience).

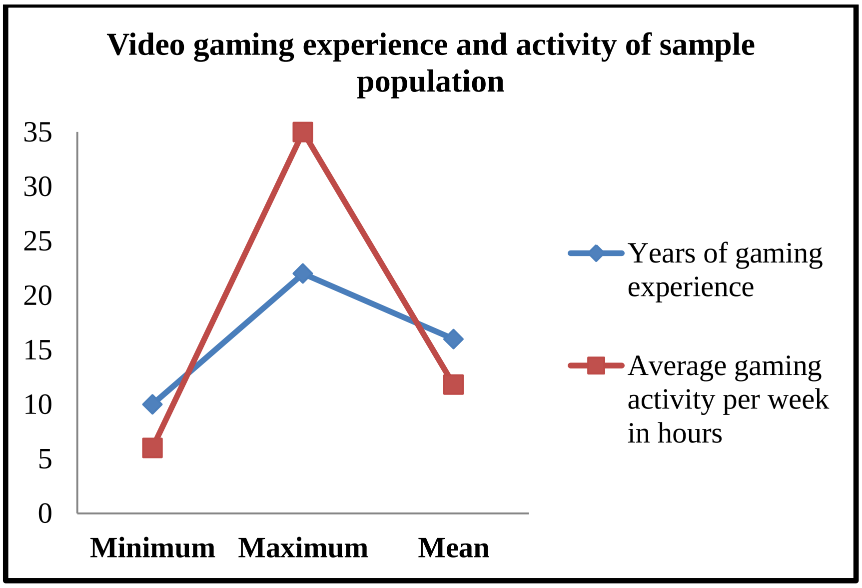


Figure 4.17 - Video gaming experience and activity of sample population

Figure 4.17 above demonstrates that the sample averaged sixteen years of prior video game experience and averaged playing video games for twelve hours per week. It is possible that the sample of VGPs acquired for this study have improved their task switching performance over the numerous years of exposure to video games to a point where their cognitive abilities cannot be improved any further through additional video game usage. This result suggests that video game practice does not improve VGPs' task switching abilities that have already had exposure to video games, especially if they report significant video game experience over long periods of time. Future studies could identify the total amount of video gaming experience an individual would require, to reach their optimal task switching performance.

The next section explores the theory that video games have no relationship with task switching abilities.

4.7.2 No relationship between video games and task switching

The acceptance of the null hypothesis in this study may also suggest that there is no relationship between video games and task switching performance. Table 4.15 that follows provides a summary of this study and the study conducted by Boot, et al. (2008) to explore how the outcomes compare.

Table 4.15 - Summary of the study by Boot, et al. (2008)

Study	Population Trained	Video Games Used	Outcome
Boot, et al. (2008)	nVGPs	MoH Tetris RoN	No evidence that suggests video game practice improves task switching performance (Boot, et al., 2008)
This study	Non-playing RTS VGPs	StarCraft	RTS video games do not improve task switching abilities

The finding that video practice does not improve task switching performance corresponds with the study by Boot, et al. (2008) (as shown in table 4.15 above). The lack of statistical backing for the task switching improvements discussed in this chapter supports the notion that the improvements that VGPs demonstrated in task switching performance was merely coincidental. Furthermore, this supports the theory that there is no relationship between video games and cognitive flexibility.

In the next section a conclusion is provided by stipulating the structure of this chapter and the various issues that were discussed.

4.8 Conclusion

In this chapter, the two research questions were presented and answered. It was found that RTS video games have no statistically significant impact on non-playing RTS VGPs' task switching performance. The possible reasons for this outcome were explored in the answers to the second research question which were divided into methodological reasons and characteristics of the sample population.

The potential explanations arising from the methodological approach that were discussed were the story mode incorporated into the RTS video game training regime, the game settings of StarCraft that were utilized, the duration of the training schedule, the problem of task-specific learning and possible interference with task switching abilities from other video game usage during the time period of the study. The characteristics of the sample population that were examined included: race and gender differences. Where applicable, results were compared to the results of the other video game training studies discussed in the literature. Finally, support for the null hypothesis was provided by investigating the effects of prior video game experience and comparing the results of this study to the results of another study with a similar outcome.

The goal of this chapter has been achieved by answering the research questions and fulfilling the purpose of this research. The next chapter concludes this dissertation by recapping the purpose of this study, reviewing the key findings and providing recommendations for future works.

Chapter 5 - Conclusion

5.1 Introduction

The goal of this chapter is to reflect on the work performed in this study and provide a summary of this dissertation. This chapter begins by providing a summary of the work done in each chapter. Thereafter, the key findings and conclusions drawn from them will be recapped. Subsequently, recommendations for future research will be made. Finally, the fulfilment of this study's purpose and the contribution it makes to the debate on the effects of video games on executive functions will be recognized.

5.2 Summary of chapters

The purpose of this study was to assess the impact of RTS video games on non-playing RTS VGPS' task switching performance. This dissertation began by introducing the two focus areas of this research (RTS video games and task switching) and placed them into context of this study. The need for this type of study was established followed by a brief summary of this study's purpose and the research questions it seeks to answer.

The goal of the second chapter was to provide a comprehensive explanation of the two focus areas of this study and establish the gap that exists in the literature. The chapter began by exploring video games in general, followed by RTS video games (the first focus area of this research) to highlight the implications they have on this study and cognitive flexibility. Discussion of task switching, the second focus area of this study, followed. The fundamentals of task switching theory were explained. Subsequently, the key concepts of task switching experiments were elucidated.

After exploring the two focus areas of this study in detail, the current state of the literature surrounding the effects of video games on executive functions were reviewed. No studies were found in the literature that assessed the impact of a particular genre of video games on current VGPs' cognitive flexibility which resulted in a gap in the literature. This study aimed to contribute to the debate on the effects of video games on cognitive flexibility by looking at the effects of a specific video game genre (RTS video games) on current VGPs' task switching performance.

The purpose of chapter three was to articulate and justify the research methods and instruments utilized in this study. The chapter began by emphasizing the importance of methodologies in research projects and expanded on the research questions to specify how this study intended to answer them. Thereafter, the research onion was presented and the research decisions taken in each layer of the research onion was elucidated. A data collection procedure section followed, which explained how the data was collected for this study.

The research instruments utilized were then explained followed by a justification for their implementation in this study. Thereafter, the ethical restrictions for conducting this research (which this study abided by) were outlined. Finally, the limitations of this study were declared in chapter three.

The aim of chapter four was to fulfil the purpose of this research by answering the research questions. To answer the research questions the key findings from the data were disclosed. Every result was followed by an analytical discussion which explored its consequences. Support was also provided for the acceptance of the null hypothesis in this study. The key findings of this research are summarized in the next section.

5.3 Key findings

The key findings of this study originated from answering the two research questions and the support for the acceptance of the null hypothesis in this study. The answer to the first research question and the crucial finding pertaining to this is summarized in the next sub-section.

5.3.1 What impact do RTS video games have on non-playing RTS VGPs' task switching performance?

Although subjects who trained in StarCraft for twenty hours over a period of four to six weeks improved in the task switching test measures, the outcome of the statistical tests on task switching performance revealed that RTS video games had no statistically significant impact on non-playing RTS VGPs' task switching performance. Hence, the null hypothesis was accepted whilst the alternative hypotheses were rejected. The statuses of these hypotheses are recapped in table 5.1 below.

Table 5.1 - Statuses of hypotheses

Hypothesis	Statement	Status
Null hypothesis (H0)	RTS video games have no impact on non-playing RTS VGPs' task switching performance	Accepted
Alternative hypothesis (H1)	RTS video games positively influence non-playing RTS VGPs' task switching performance	Rejected
Alternative hypothesis (H2)	RTS video games negatively influence non-playing RTS VGPs' task switching performance	Rejected

The outcomes of the video game training studies covered in this dissertation are recapped in table 5.2 that follows. The result of accepting the null hypothesis is also included to demonstrate how it compares to the outcomes of previous studies surrounding the effects of video games on cognitive flexibility.

Table 5.2 - State of the video game training literature and this study

Study	Population Trained	Games Used	Outcome
Basak, et al. (2008)	nVGPs	RoN	Video game training has a beneficial effect on task switching ability (Basak, et al., 2008).
Green, et al. (2012) (Experiment four)	nVGPs	UT 2004 CoD 2 The Sims 2	Marginally significant positive effect on task switching performance (Green, et al., 2012).
Glass, et al. (2013)	nVGPs	StarCraft	RTS video game settings that promote rapid assessment and coordination across multiple sources of information enhances cognitive flexibility (Glass, et al., 2013).
Boot, et al. (2008)	nVGPs	MoH Tetris RoN	No evidence that suggests video game practice improves task switching performance (Boot, et al., 2008).
This study	**Non-playing RTS VGPs**	**StarCraft**	**RTS video games do not improve task switching abilities.**

The next research question sought to ascertain the reasons that could explain the ineffectiveness of RTS video games as a tool for enhancing non-playing RTS VGPs' task switching performance. The causes that were discussed are summarized next.

5.3.2 Why do RTS video games impact task switching performance in the way they do?

Various possibilities were explored to provide answers for this second research question. The potential reasons that explain the ineffectiveness of an RTS video game as a mechanism for improving task switching abilities were divided into two sections and discussed: the methodological approach followed by the characteristics of the sample population. However, the possible explanations for the improvement noted in experimental group members' task switching performance (who trained in StarCraft for twenty hours) were also identified. The next section summarizes the possible explanations arising from the methodology that may explain the main finding.

- **Methodological**

The methodological details that will be recapped include: game performance, story mode of StarCraft, game settings, training schedule, task-specific learning and interference from other video gaming activity.

- **Game performance**

The measurement of players' performances in StarCraft revealed that they improved after twenty hours of practice over a period of time. This improvement could explain the players' improvement in the post-training task switching test measures. The outcome of the analysis suggested that improvement in a RTS video game such as StarCraft translated into enhanced task switching abilities. However, this theory lacked statistical backing.

- **StarCraft's story mode and game settings**

Players were permitted to play StarCraft's story mode. As demonstrated in section 4.6.1 the behaviour and actions of the computer-controlled opponents in this mode are not as challenging as other scenarios in the game and are designed to be beaten to make the story mode of game more fun (Blizzard Entertainment, 2014). Furthermore, the game settings were kept to its default and were not altered in any way. This easier difficulty setting and reduced task switching demands could explain the inability of players to adequately improve their performances in the post-training task switching test measures to reject the null hypothesis.

- **Training schedule and task-specific learning**

The training regime which consisted of a total of twenty hours of RTS video game training over a period of four to six weeks may not have been adequate to trigger sufficient changes in players' task switching performance.

The same task switching test measure was utilized in the pre and post-training test batteries of this study confirming the issues of task-specific learning as indicated by (Green, et al., 2012). The task-specific learning problem arises as a result of using the same task-switching test measure on a sample more than once.

Repeated use of the same task switching test measure will cause subjects to improve in that task. This reduces the effectiveness and accuracy of a task switching test battery as an instrument for measuring task switching abilities. The reasons not to utilize different task switching tests in the pre and post-training task switching test batteries were addressed in section 3.4.6 of chapter three.

- **Interference from other video gaming activity**

Participants continued their normal video gaming habits throughout the duration of this study. It remains a possibility that their daily video game usage and exposure may have affected their performances in the task switching test batteries. However, no data was collected on participants' video gaming activity between the pre and post-training task switching test batteries. Additionally, it was established that people require reasonable task switching skills when playing casual games and performing other tasks of everyday life simultaneously. These types of games could have impacted subjects' performances in the task switching test batteries since a fair number of the sample reported playing these types of games.

The characteristics of the sample population that may explain the findings will now be recapped as planned.

- **Sample population**

Several aspects of the sample population were identified that may have contributed to the conclusions arising from the results of the task switching test measures in this study. The characteristics that will be revisited are: race, gender and prior video gaming experience.

- **Self-reported Coloured subjects**

Two subjects who self-reported being Coloured demonstrated poorer performance in the post-training task test than in the pre-training tests. However, their task switching performances in the pre and post-training tests were superior to the performances of the sample average. Further analysis revealed that they reported more usage in specific video game genres than the rest of the sample. These video game genres included role-playing, fighting and sports video games. The higher usage in the sports video game genre could have developed their task switching skills to their maximum potential.

- **Gender: females**

Although it could not be statistically proven, females from the experimental group substantially improved their task switching performance after training in StarCraft for twenty hours. Their task switching performances were compared to females from the control group who did not train in RTS video games. Females in the control group performed similarly in both the pre and post-training task switching test batteries. This result suggests that RTS video games may be especially effective tools for improving females' task switching ability.

The improvements of males and females' task switching performances that underwent training in StarCraft were compared to gather additional evidence to support this theory. This comparison revealed that the improvement females demonstrated in task switching abilities after twenty hours of StarCraft training was far superior to the improvement males exhibited. Thereafter the female improvement in this study was compared to the performances of females in other studies concerned with the effects of video games on task switching abilities. This analysis supports the theory that RTS video games are better suited for improving females' cognitive flexibility than males.

5.3.3 Support for null hypothesis acceptance

The possible explanations which deemed the acceptance of the null hypothesis appropriate were explored. The video game experience of the sample of this study was inspected followed by an examination of the theory that video games have no relationship with task switching abilities.

- **Prior video game experience**

The statistics on the experience of the sample population revealed that the sample averaged sixteen years of prior video game experience and averaged playing video games for twelve hours per week. It remains a possibility that the sample of VGPs acquired for this study have improved their task switching performance over the numerous years of exposure to video games to a point where their cognitive abilities cannot be improved any further through additional video game usage. This finding suggested that video game practice does not improve VGPs' task switching abilities that have already had exposure to video games, especially if they report significant video game experience over long periods of time.

- **No relationship between video games and task switching**

The finding that video practice does not improve task switching performance were compared to other similar studies and was found to correspond with conclusions derived by Boot, et al. (2008). The lack of statistical backing for the task switching improvements noted in this research supports the notion that the improvements that VGPs demonstrated in task switching performance was merely coincidental. This finding also supported the theory that there is no relationship between video games and cognitive flexibility.

The final section of this dissertation provides recommendations for future research surrounding the video game and cognitive flexibility field.

5.4 Recommendations for future research

In this section methodological recommendations have been made for carrying out future research associated with the training effects of video games on cognitive flexibility. Thereafter, areas for future research related to the effects video games and executive functions have been identified.

5.4.1 Methodological

The methodological recommendations for future studies include: game performance, the story mode of StarCraft, game settings, training schedule, task-specific learning and video gaming activity in current VGPs.

- **Game performance measurement**

To measure game performance, a model similar to the one derived by Glass, et al. (2013) could be utilized that pinpoint which game features in the near past drove user actions in the present and more importantly how much task switching players perform in a StarCraft scenario. This model, together with detailed in-game data could be used to determine if the task switching in StarCraft scenarios correlates with improved task switching performance.

- **Story mode**

In future studies the story mode of StarCraft could be utilized as a tutorial to allow players to gain an understanding of the mechanics on all three races and the functions each unit in the game serves. However, the primary focus should remain on skirmishes against a computer-controlled opponent or another player. The story mode of the game can require a significant time to complete. Hence, a training regime which includes more practice hours that is run over a longer period of time can facilitate the completion of the story mode and leave players with adequate time to play skirmishes against computer-controlled opponents or other players.

- **Game settings**

The findings of this study supports the claim made by Glass, et al. (2013) that RTS video games only improve cognitive flexibility in scenarios that promote task switching on a high scale across multiple information sources. The configuration of StarCraft could be altered in future studies in a manner that demands players to rapidly switch between performing various tasks across numerous sources of information to enhance task switching abilities.

Glass, et al. (2013) provides a methodology for encouraging this quick task switching across multiple sources of information in StarCraft. Skirmishes against computer-controlled opponents or other players should begin with two friendly bases and two enemy bases in different locations of the game world from the beginning of the scenario. This results in multiple battles against both bases which promotes more task switching and coordination of cognitive resources than the game’s default settings (Glass, et al., 2013).

Furthermore, disabling the visual alerts and audio alerts encourages faster thinking because it compels players to rely on memory to determine events that occur on areas of the game world that are not currently visible on screen (Glass, et al., 2013).

- **Training schedule**

Participants could train for long durations before assessing the impact of RTS video games on task switching performance. Ideally, the training regime implemented by Green, et al. (2012)

who had participants train for a total of fifty hours over a period of six to fourteen weeks should be followed. Moreover, training over a considerably longer period of time may be necessary before any statistically significant changes can be observed in a sample which reports substantial prior video game usage and experience.

- **Task-specific learning**

In a video game training study, different task switching test batteries could be utilized in pre and post-training test measures to prevent task-specific learning from occurring.

- **Other video gaming activity for current VGPs**

To observe the effects of training in a specific video game genre on current VGPs, participants could be instructed to stop all other video gaming activity for the duration of the training schedule. Alternatively, all their video gaming activities during the training program could be recorded. This may eliminate the problem of the effects of other video gaming activity on task switching abilities.

5.4.2 Areas for future research

The key areas for future research that will be identified in this section includes: sports video games, casual games on mobile devices, gender differences, prior video game experience and transfers to real-world situations.

- **Sports video games**

An avenue for future research would be to investigate the various types of sports video games in the simulation video game genre, and assess their effects on cognitive flexibility.

- **Casual games on mobile devices**

As discussed in section 4.6.1 of chapter three, many subjects from the sample population reported playing casual games. It was established that these games do not require task switching on a high scale. However, the task switching challenge arises from playing these games on mobile devices whilst performing other tasks of everyday life simultaneously. The widespread use of these types of games (Mazin, 2011) opens up avenues for future research which could assess the impact of casual games on task switching ability, particularly in real-world scenarios.

- **Gender differences**

The gender analysis for this study revealed that RTS video games had stronger effects on females' task switching performance than males. Future research could investigate gender differences on the cognitive benefits of video games. Moreover, gender differences in the nature of these transfers into real-world environments can be examined.

- **Video game experience**

Future studies could identify the total amount of video gaming experience a person would need to reach their optimal cognitive flexibility performance.

- **Transfers to real-world situations**

As a final note on recommendations for future research, any improvements in task switching performance noted in controlled settings as a result of video game practice could be tested in real-world situations in future studies, before video game training can be deemed beneficial.

The last section of this chapter concludes this dissertation by acknowledging that the purpose of this study has been fulfilled, and its contribution to the literature.

5.5 Conclusion

In this chapter, a summary of this dissertation was provided and the key findings were recapped. Recommendations have been made regarding the method in which RTS video games should be applied for the purpose of improving task switching ability. Additionally, areas for future research associated with the effects of video games on executive functions were indicated.

This study implemented a RTS video game in a specific way on non-playing RTS VGPs and measured its impact on their task switching performance. The results and conclusions drawn from this study augment previous researchers' understanding about the effects of video games on executive functions thereby contributing to the field of study. Finally, the gender differences of the effects of video games on cognitive flexibility recorded in this study could be an engaging avenue for future works.

Reference List

2015 Inc. (2002). Medal of Honor: Allied Assault: Electronic Arts.

Adams, E. (2009). *Fundamentals of Game Design* (2nd ed.): New Riders.

Adams, E. (2013). *Fundamentals of Game Design* (3rd ed.): Pearson Education.

Adams, E., & Dormans, J. (2012). *Game mechanics: advanced game design*: New Riders.

Adams, G. R., & Schvaneveldt, J. D. (1991). *Understanding research methods* (2nd ed.). New York: Longman.

Alexopoulos, G. S., Raue, P., & Areán, P. (2003). Problem-solving therapy versus supportive therapy in geriatric major depression with executive dysfunction. *The American journal of geriatric psychiatry, 11*(1), 46-52.

Aliaga, M., & Gunderson, B. (2002). *Interactive statistics*. New Jersey: Prentice Hall.

Allport, A., Styles, E. A., & Hsieh, S. (1994). Shifting attentional set: Exploring the dynamic control of tasks. *C. Umilta & M. Moscovitch (Eds.), Attention and performance XV: Conscious and nonconscious information processing*, 421-452.

Allport, A., & Wylie, G. (2000). Task switching, stimulus-response bindings, and negative priming. *Control of cognitive processes: Attention and performance XVIII*, 35-70.

Anderson, C. A., & Bushman, B. J. (2001). Effects of violent video games on aggressive behavior, aggressive cognition, aggressive affect, physiological arousal, and prosocial behavior: A meta-analytic review of the scientific literature. *Psychological Science, 12*(5), 353-359.

Apperley, T. H. (2006). Genre and game studies: Toward a critical approach to video game genres. *Simulation & Gaming, 37*(1), 6-23. doi: 10.1177/1046878105282278

Atkinson, G., & Bouma, G. (1995). A Handbook of social science research: A comprehensive and practical guide for students. *American Sociological Association, 25*(1), 86-88.

Badre, D., & Wagner, A. D. (2006). Computational and neurobiological mechanisms underlying cognitive flexibility. *PNAS, 103*, 7186–7191.

Bakalar, J. (2009). Xbox 360 vs. PlayStation 3 vs. Wii: Updated Retrieved 17th April, 2012, from http://www.cnet.com/au/news/xbox-360-vs-playstation-3-vs-wii-updated/

Baniqued, P. L., Kranz, M. B., Voss, M. W., Lee, H., Cosman, J. D., Severson, J., et al. (2013). Cognitive training with casual video games: points to consider. *Frontiers in psychology, 4*.

Baniqued, P. L., Lee, H., Voss, M. W., Basak, C., Cosman, J. D., DeSouza, S., et al. (2013). Selling points: What cognitive abilities are tapped by casual video games? *Acta psychologica, 142*(1), 74-86.

Basak, C., Boot, W. R., Voss, M. W., & Kramer, A. F. (2008). Can training in a real-time strategy video game attenuate cognitive decline in older adults? *Psychology and aging, 23*(4), 765.

Beck, J. (2002). Positional Games In B. Bollobas (Ed.), *Contemporary Combinatorics*. Budapest: Springer.

Biernacki, P., & Waldorf, D. (1981). Snowball sampling: Problems and techniques of chain referral sampling. *Sociological methods & research, 10*(2), 141-163.

Big Huge Games. (2003). Rise of Nations: Microsoft Game Studios.

Bilton, N. (2011). Video Game Industry Continues Major Growth, Gartner Says. *The New York Times* Retrieved 12th June, 2012, from http://bits.blogs.nytimes.com/2011/07/05/video-game-industry-continues-major-growth-gartner-says/

Bioware. (2007). Mass Effect: Microsoft Game Studios.

Bioware. (2010). Mass Effect 2: Electronic Arts.

Bioware. (2012). Mass Effect 3: Electronic Arts.

Blizzard Entertainment. (1999). StarCraft: Blizzard Entertainment.

Blizzard Entertainment. (2004). World of Warcraft: Blizzard Entertainment.

Blizzard Entertainment. (2014). Frequently Asked Questions: AI Scripts Retrieved 13th July, 2014, from http://classic.battle.net/scc/faq/aiscripts.shtml

Blumberg, F. C., Rosenthal, S. F., & Randall, J. D. (2008). Impasse-driven learning in the context of video games. *Computers in Human Behavior, 24*(4), 1530-1541.

Boot, W. R., Kramer, A. F., Simons, D. J., Fabiani, M., & Gratton, G. (2008). The effects of video game playing on attention, memory, and executive control. *Acta psychologica, 129*(3), 387-398. doi: 10.1016/j.actpsy.2008.09.005

Boutellier, R., Gassmann, O., Raeder, S., & Zeschky, M. (2013). Research Methodology: How to qualitative and quantitative research differ? Retrieved 19th March, 2014, from http://www.tim.ethz.ch/education/courses/courses_fs_2013/DocSem_Fall13/10_summary

Brathwaite, B., & Schreiber, I. (2008). *Challenges for Game Designers*: Cengage Learning.

Bullfrog. (1991). Populous II: Electronic Arts.

Butler, S., & Dee, K. C. (2012). *Students who take more time to switch between tasks report more video game usage*. Paper presented at the American Society for Engineering Education, Indiana.

Cain, M. S., Landau, A. N., & Shimamura, A. P. (2012). Action video game experience reduces the cost of switching tasks. *Attention, perception & psychophysics, 74*, 641-647.

Campbell, D., & Stanley, J. (1966). *Experimental and quasi-experimental designs for research* (1st ed.): Cengage Learning.

Carmichael, S. (2014). Angry Birds downloads cross 2 billion Retrieved 1st February, 2014, from http://www.gamezone.com/news/2014/01/23/angry-birds-downloads-cross-2-billion

Chisholm, J. D., Hickey, C., Theeuwes, J., & Kingstone, A. (2010). Reduced attentional capture in action video game players. *Attention, Perception, & Psychophysics, 72*(3), 667-671.

Churchill, D., & Buro, M. (2011). *Build Order Optimization in StarCraft.* Paper presented at the Seventh AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment.

Clark, J. E., Lanphear, A. K., & Riddick, C. C. (1987). The effects of videogame playing on the response selection processing of elderly adults. *Journal of Gerontology, 42*(1), 82-85.

Claypool, M., LaPoint, D., & Winslow, J. (2003). *Network analysis of counter-strike and starcraft.* Paper presented at the Performance, Computing, and Communications Conference, 2003. Conference Proceedings of the 2003 IEEE International.

Colzato, L. S., van Leeuwen, P. J. A., van den Wildenberg, W. P. M., & Hommel, B. (2010). DOOM'd to Switch: Superior Cognitive Flexibility in Players of First Person Shooter Games. *Frontiers in psychology, 1*, 8. doi: 10.3389/fpsyg.2010.00008

Colzato, L. S., Van Wouwe, N. C., Lavender, T. J., & Hommel, B. (2006). Intelligence and cognitive flexibility: Fluid intelligence correlates with feature “unbinding” across perception and action. *Psychonomic bulletin & review, 13*(6), 1043-1048.

Cooper-Kahn, J., & Dietzel, L. (2008). What Is Executive Functioning? Retrieved 26th March, 2014, from http://www.ldonline.org/article/29122/

Cooper, D. R., & Schindler, P. S. (2008). *Business Research Methods* (10th ed.). USA: McGraw-Hill.

Cooper, D. R., & Schindler, P. S. (2011). *Business Research Methods* (11th ed.). USA: McGraw-Hill/Irwin.

Crawford, C. (2011). *The Art Of Computer Game Design: Reflections Of A Master Game Designer*: McGraw-Hill.

Criss, B. R. (2006). Gender differences in multitasking. *National Undergraduate Research Clearinghouse, 9*.

Crone, E. A., Richard Ridderinkhof, K., Worm, M., Somsen, R. J., & Van Der Molen, M. W. (2004). Switching between spatial stimulus–response mappings: A developmental study of cognitive flexibility. *Developmental science, 7*(4), 443-455.

Deak, G. O. (2003). The development of cognitive flexibility and language abilities. *Advances in child development and behavior, 31*, 273-328.

Dorval, M., & Pepin, M. (1986). Effect of playing a video game on a measure of spatial visualization. *Perceptual & Motor Skills, 62*, 159-162.

Dredge, S. (2013). Candy Crush Saga reaches 500m installations on mobile and Facebook Retrieved 15th July, 2014, from http://www.theguardian.com/technology/2013/nov/15/candy-crush-saga-reaches-500m-installs-mobile-facebook

Dubois, B., Slachevsky, A., Litvan, I., & Pillon, B. (2000). The FAB: A frontal assessment battery at bedside. *Neurology, 55*(11), 1621-1626.

Edge. (2007). Edge's top 100 games of all time Retrieved 1st April, 2014, from http://web.archive.org/web/20080202064950/http://www.next-gen.biz/index.php?option=com_content&task=view&id=6231&Itemid=2&limit=1&limitstart=6

Egli, E. A., & Meyers, L. S. (1984). The role of video-game playing in adolescent life: Is there a reason to be concerned? *Bulletin of the Psychonomic Society, 22*, 309-312.

Electronic Arts Canada. (2013). Fifa 14: Electronic Arts.

Elliott, L., Golub, A., Ream, G., & Dunlap, E. (2012). Video Game Genre as a Predictor of Problem Use. [Article]. *CyberPsychology, Behavior & Social Networking, 15*(3), 155-161. doi: 10.1089/cyber.2011.0387

Elliott, R. (2003). Executive functions and their disorders Imaging in clinical neuroscience. *British Medical Bulletin, 65*(1), 49-59.

Epic Games, Digital Extremes, Psyonix, & Streamline Studios. (2004). Unreal Tournament 2004: Atari.

Esposito, N. (2005). *A Short and Simple Definition of What a Videogame Is.* Paper presented at the DiGRA 2005 Conference: Changing Views – Worlds in Play.

Fabricatore, C. (2007). *Gameplay and game mechanics design: a key to quality in videogames.* Paper presented at the OECD-CERI Expert Meeting on Videogames and Education.

Fatt, B., & Gamepro. (2007). The 52 Most Important Video Games of All Time Retrieved 28th March, 2014, from http://web.archive.org/web/20080913085022/http://www.gamepro.com/article/features/110068/the-52-most-important-video-games-of-all-time-page-4-of-8/

Feldman, A., & Feldman, A. (2001). *Designing arcade computer game graphics*: Wordware Pub.

Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychological science, 18*(10), 850-855.

Ferguson, C. J., Cruz, A. M., & Rueda, S. M. (2007). Gender, video game playing habits, and visual memory tasks. *Sex Roles, 58*, 279-286.

Frank, O., & Snijders, T. (1994). Estimating the size of hidden populations using snowball sampling. *Journal of Official Statistics, 10*, 53-53.

Frederiksen, J. R., & White, B. Y. (1989). An approach to training based upon principled task decomposition. *Acta psychologica, 71*(1), 89-146.

Frictional Games. (2011). Amnesia: The Dark Descent: Frictional Games.

Funahashi, S. (2001). Neuronal mechanisms of executive control by the prefrontal cortex. *Neuroscience research, 39*(2), 147-165.

Funaki, S. (1981). Pac-Man: Namco.

Garland, J. (2014). Five incredible ways Oculus Rift will go beyond gaming Retrieved 3rd February, 2014, from http://www.techradar.com/news/gaming/5-incredible-ways-oculus-rift-will-go-beyond-gaming-1220211

Garmon, J. (2005). Geek Trivia: First shots fired Retrieved 15th October, 2013, from http://www.techrepublic.com/article/geek-trivia-first-shots-fired/

Gilbert, S. J., & Shallice, T. (2002). Task switching: A PDP model. *Cognitive Psychology, 44*, 297–337.

Gill, J., & Johnson, P. (2002). *Research Methods for Managers* (3rd ed.). London: Sage Publications, Inc.

Given, L. M. (2008). *The Sage encyclopedia of qualitative research methods* (Vol. 2): Sage Publications, Inc.

Glass, B. D. (2013). Cognitive Flexibility and Real-Time Strategy Game - A Project Repository Retrieved 13th March, 2014, from http://www.homepages.ucl.ac.uk/~ucacbgl/coggame/coggame.htm#Video_Game_-_StarCraft

Glass, B. D., Maddox, W. T., & Love, B. C. (2013). Real-Time Strategy Game Training: Emergence of a Cognitive Flexibility Trait. *PLOS one 8*(8), 1-7 e70350.

Goodman, L. A. (1961). Snowball sampling. *The annals of mathematical statistics*, 148-170.

Gopher, D., Armony, L., & Greenshpan, Y. (2000). Switching tasks and attention policies. *Journal of Experimental Psychology: General, 129*(3), 308-339.

Gopher, D., Well, M., & Bareket, T. (1994). Transfer of skill from a computer game trainer to flight. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 36*(3), 387-405.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*, 534-537.

Green, C. S., & Bavelier, D. (2006). Enumeration versus multiple object tracking: The case of action video game players. *Cognition, 101*, 217-245.

Green, C. S., & Bavelier, D. (2007). Action-video-game experience alters the spatial resolution of vision. *Psychological Science, 18,* 88-94.

Green, C. S., & Bavelier, D. (2012). Learning, Attentional Control, and Action Video Games. *Current Biology, 22*(6), 197-206.

Green, C. S., Sugarman, M. A., Medford, K., Klobusicky, E., & Bavelier, D. (2012). The effect of action video game experience on task-switching. *Computers in Human Behavior, 28*(3), 984-994.

Greenfield, P. M., deWinstanley, P., Kilpatrick, H., & Kaye, D. (1994). Action video games and informal education: Effects on strategies for dividing visual attention. *Journal of Applied Developmental Psychology, 15*(1), 105-123.

Griffith, J. L., Voloschin, P., Gibb, G. D., & Bailey, J. R. (1983). Differences in eye-hand motor coordination of video-game users and non-users. *Perceptual & Motor Skills, 57*(1), 155-158.

Gunn, E. A. A., Craenen, B. G. W., & Hart, E. (2009). *A Taxonomy of Video Games and AI.* Paper presented at the AISB 2009.

Hakim, C. (2000). *Research design: successful designs for social and economic research*: Psychology Press.

Halpern, D. F. (1986). *Sex differences in cognitive abilities*. Hillsdale NJ: Lawrence Erlbaum Associates.

Hart, S. G., & Battiste, V. (1992). *Field test of video game trainer.* Paper presented at the Human Factors and Ergonomics Society Annual Meeting.

Howland, G. (1999). Game Design: The Addiction Element Retrieved 11th February, 2014, from http://archive.gamedev.net/archive/reference/articles/article263.html

IGN. (1999). SimCity 3000 Retrieved 12th January, 2014, from http://www.ign.com/articles/1999/02/23/simcity-3000

IGN. (2013). Best PC Graphics. *Best of 2013* Retrieved 16th March, 2014, from http://www.ign.com/wikis/best-of-2013/Best_PC_Graphics

Infinity Ward. (2005). Call of Duty 2: Activision, Santa Monica, CA.

International Digital Times. (2013). Pokémon X And Y Sales: New Pokémon Breaks All Sales Records, Sells 4 Million Copies In Two Days Retrieved 25th October, 2013, from http://www.idigitaltimes.com/articles/20427/20131019/pokemon-x-and-y-sales-records-reviews.htm

Irrational Games. (2013). Bioshock Infinite: 2K Games.

Jersild, A. T. (1927). Mental set and shift. *Archives of psychology, 14*(89), 1-81.

Juul, J. (2001). Games Telling Stories? A Brief Note on Games and Narratives. *Game Studies, 1*(1).

Kanev, K., & Sugiyama, T. (1998). Design and Simulation of Interactive 3D Computer Games. *Computers & Graphics, 22*(2-3), 281-300.

Karle, J. W., Watter, S., & Shedden, J. M. (2010). Task switching in video game players: Benefits of selective attention but not resistance to proactive interference. *Acta psychologica, 134*(1), 70-78. doi: 10.1016/j.actpsy.2009.12.007

Kasavin, G. (1999). SimCity 3000 Review Retrieved 12th January, 2014, from http://www.gamespot.com/reviews/simcity-3000-review/1900-2533007/

Katz, H. (2006). *Global Surveys or multi-national surveys? On sampling for global surveys.* Paper presented at the Thoughts for the Globalization and Social Science Data Workshop UCSB.

Keller, G., & Warrack, B. (2000). *Statistics for management and economics.* (5th ed.). Pacific Grove: Duxbury Press.

King. (2012). Candy Crush Saga: King.

King, D., Delfabbro, P., & Griffiths, M. (2010). Video game structural characteristics: A new psychological taxonomy. *International Journal of Mental Health and Addiction, 8*(1), 90-106.

King, G., & Krzywinska, T. (2002). *Screenplay: cinema/videogames/interfaces*: Wallflower Press.

Kitase, Y. (2010). Final Fantasy XIII: Square Enix.

Kluwe, R. H. (1982). Cognitive knowledge and executive control: Metacognition *Animal mind—human mind* (pp. 201-224): Springer.

Kuhns, D. (2007). *The effects of endogenous and exogenous cues on task-set inhibition.* Master of Arts in Interdisciplinary Studies, Oregon State University.

Lara-Cabrera, R., Cotta, C., & Fernández-Leiva, A. J. (2013, 16-19 April 2013). *A review of computational intelligence in RTS games.* Paper presented at the Foundations of Computational Intelligence (FOCI), 2013 IEEE Symposium on (pp. 114-121). IEEE.

Logan, G. D., & Bundesen, C. (2003). Clever homunculus: Is there an endogenous act of control in the explicit task-cuing procedure? *Journal of Experimental Psychology: Human Perception and Performance, 29,* 575–599.

Lubbe, S., & Klopper, R. (2004). Introduction to Research Design in Information Communication Technology. Durban: Dolphin Coast Publishers.

LucasArts. (1993). Star Wars: Rebel Assault: LucasArts.

Lyon, G., & Krasnegor, N. A. (1996). *Attention, memory, and executive function*: Paul H Brookes Publishing.

Macionis, J. J., & Gerber, L. M. (2011). Sociology: Seventh Canadian Edition: Pearson Education Canada.

Matsuda, G., & Hiraki, K. (2006). Sustained decrease in oxygenated hemoglobin during video games in the dorsal prefrontal cortex: a NIRS study of children. *Neuroimage, 29*(3), 706-711.

Maxis. (1999). SimCity 3000: EA Games.

Maxis. (2000). The Sims: Electronic Arts.

Maxis. (2004). The Sims 2: Electronic Arts.

Mayr, U., & Keele, S. W. (2000). Changing internal constraints on action: the role of backward inhibition. *Journal of Experimental Psychology: General, 129*(1), 4.

Mazin, L. (2011). Are You Addicted to Angry Birds? [INFOGRAPHIC] Retrieved 16th June, 2014, from https://aytm.com/blog/research-junction/angry-birds-addiction/

McClure, R. F., & Mears, F. G. (1984). Video game players: Personality characteristics and demographic variables. *Psychological Reports, 55*(1), 271-276.

McClurg, P. A., & Chaillé, C. (1987). Environments for developing spatial cognition. *Journal of Educational Computing Research, 3*(1), 95-111.

McGonigal, J. (Producer). (2010). Jane McGonigal: Gaming can make a better world. *TED Talks*. Retrieved from http://blog.ted.com/2010/03/17/gaming_can_make/

Meiran, N. (1996). Reconfiguration of processing mode prior to task performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*(6), 1423.

Meiran, N., Chorev, Z., & Sapir, A. (2000). Component processes in task switching. *Cognitive Psychology, 41*(3), 211-253.

Meyer, D., Evans, J., Lauber, E., Rubinstein, J., Gmeindi, L., Junck, L., et al. (1997). *Activation of brain mechanisms for executive mental processes in cognitive task switching.* Paper presented at the Poster presented at the fourth annual meeting of the Cognitive Neuroscience Society.

Microsoft Game Studios. (2006). Microsoft Flight Simulator: Microsoft Game Studios.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual review of neuroscience, 24*(1), 167-202.

Miller, S. (2010). The History of Puzzle Games Retrieved 11th February, 2014, from http://web.archive.org/web/20100204081152/http://www.gamespot.com/features/vgs/universal/puzzle_hs/

Mitchell, V. (1996). Assessing the reliability and validity of questionnaires: an empirical example. *Journal of Applied Management Studies, 5*, 199-208.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49-100.

Monsell, S. (2003). Task Switching. *Trends in Cognitive Sciences, 7*(3), 7. doi: 10.1016/S1364-6613(03)00028-7

Monsell, S., & Driver, J. (2000). *Control of cognitive processes: Attention and performance XVIII* (Vol. 18): MIT Press.

Moore, A., & Malinowski, P. (2009). Meditation, mindfulness and cognitive flexibility. *Consciousness and cognition, 18*(1), 176-186.

Mouton, J., & Babbie, E. (2001). The practice of social research. *Cape Town: Wadsworth Publishing Company*.

Muijs, D. (2010). *Doing Quantitative Research in Education with SPSS*: Sage

Naëgelé, B., Thouvard, V., Pépin, J.-L., & Lévy, P. (1995). Deficits of cognitive executive functions in patients with sleep apnea syndrome. *Sleep: Journal of Sleep Research & Sleep Medicine*.

Nakago, T., Morita, K., & Nishida, Y. (1985). Super Mario Bros.: Nintendo.

NetherRealm Studios. (2011). Mortal Kombat: Warner Bros. Interactive Entertainment.

Nintendo. (2005). Big Brain Academy.

Norman, D., & Shallice, T. (1986). Attention to action: willed and automatic control of behavior. In R. Davidson, R. Schwartz & D. Shapiro (Eds.), *Consciousness and Self-Regulation: Advances in Research and Theory IV*: Plenum Press.

O'Neill, P. H. (2014). 'StarCraft: Brood War' proves the best esports are timeless Retrieved 17th July, 2014, from http://www.dailydot.com/esports/starcraft-brood-war-starleague-esports-survive/

Orosy-Fildes, C., & Allan, R. W. (1989). Psychology of computer use: XII. Video game play: Human reaction time to visual stimuli. *Perceptual and Motor Skills, 69*, 243-247.

Orvis, K. A., Horn, D. B., & Belanich, J. (2006). Video game-based training success: The impact of trainee characteristics - Year 2 *Technical Report, 1188*. Arlington, VA: United States Army Research Institute for the Behavioral and Social Sciences.

Pajitnov, A. (1984). Tetris. Moscow.

Park, H., Lee, K., Cho, H.-C., & Kim, K.-J. (2012). *Prediction of early stage opponents strategy for StarCraft AI using scouting and machine learning.* Paper presented at the Proceedings of the Workshop at SIGGRAPH Asia.

Pillay, H. (2002). An investigation of cognitive processes engaged in by recreational computer game players: Implications for skills of the future. *Journal of Research on Computing in Education, 34*(3), 336-350.

Pinelle, D., Wong, N., & Stach, T. (2008). *Using genres to customize usability evaluations of video games.* Paper presented at the Conference on Future Play: Research, Play, Share, Toronto, Ontario, Canada.

Poh, M. (2013). Evolution Of Video Games User Interface (UI) Retrieved 21st March, 2014, from http://www.hongkiat.com/blog/video-games-ui-evolution/

Prato, G. D., Feijóo, C., Nepelski, D., Bogdanowicz, M., & Simon, J. P. (2010). Born digital/grown digital: Assessing the future competitiveness of the EU video games software industry *JRC Scientific and Technical Report* Luxembourg.

Purchese, R. (2010). StarCraft II sells 3 million in a month Retrieved 22nd October, 2012, from http://www.eurogamer.net/articles/2010-09-01-starcraft-ii-sells-3-million-in-a-month

Quaiser-Pohl, C., Geiser, C., & Lehmann, W. (2006). The relationship between computer-game preference, gender, and mental-rotation ability. *Personality and Individual Differences, 40,* 609-619.

Rajasekar, S., Philominathan, P., & Chinnathambi, V. (2006). Research methodology. Retrieved from http://arxiv.org/pdf/physics/0601009.pdf

Robson, C. (2002). *Real World Research* (2nd ed.). Oxford Blackwell Publishing.

Rogers, R. D., & Monsell, S. (1995). Costs of a predictible switch between simple cognitive tasks. *Journal of experimental psychology, 124*(2), 207-231.

Rollings, A., & Adams, E. (2003). *Andrew Rollings and Ernest Adams on Game Design* (1st ed.): New Riders.

Rollings, A., & Morris, D. (2000). *Game Architecture and Design*. Scottsdale, Arizona: Coriolis.

Rouse, R. (2004). *Game Design: Theory and Practice* (1st ed.): Jones & Bartlett Learning.

Rouse, R. (2010). *Game Design: Theory and Practice* (2nd ed.): Jones & Bartlett Learning.

Rovio Entertainment. (2009). Angry Birds: Chillingo, Clickgamer, Rovio Entertainment.

Rubinstein, J. S., Meyer, D. E., & Evans, J. E. (2001). Executive control of cognitive processes in task switching. *Journal of Experimental Psychology: Human Perception and Performance, 27*(4), 763.

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research Methods for Business Students* (5th ed.). New Jersey: Prentice Hall.

Schneider, D. W., & Logan, G. D. (2005). Modeling task switching without switching tasks: A short-term memory priming account of explicitly cued performance. *Journal of Experimental Psychology: General, 134*, 343-367.

Scott, W. A. (1962). Cognitive Complexity and Cognitive Flexibility. *Sociometry, 25*(4), 405-414. doi: 10.2307/2785779

Seeley, W. W., Menon, V., Schatzberg, A. F., Keller, J., Glover, G. H., Kenna, H., et al. (2007). Dissociable intrinsic connectivity networks for salience processing and executive control. *The Journal of neuroscience, 27*(9), 2349-2356.

Sekaran, U. (1992). *Research Methods for Business: A Skill-Building Approach.* (2nd ed.). Brisbane: John Wiley & Sons Inc.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*: Wadsworth Cengage learning.

Sibanda, N. (2009). Quantitative Research Retrieved 17th March, 2014, from http://www.victoria.ac.nz/postgradlife/downloads/quantitative%20seminar18Aug09.pdf

Simons, I., & Newman, J. (2004). *Difficult Questions About Video Games*: Suppose Partners.

Sonic Team. (1991). Sonic the Hedgehog: Sega.

Sudevan, P., & Taylor, D. A. (1987). The cuing and priming of cognitive operations. *Journal of Experimental Psychology: Human Perception and Performance, 13*(1), 89.

Svendsen, J. B., & Rathe, E. A. (2012). *Micromanagement in Starcraft using potential fields tuned with a multi-objective genetic algorithm.* Master of Science, Norwegian University of Science and Technology.

Tashakkori, A., & Teddlie, C. (2010). *Sage handbook of mixed methods in social & behavioral research* (2nd ed.): SAGE Publications, Inc.

Technology, L. I. O. M. A. (2014). Research Methodology: An Introduction Retrieved 14th May, 2014, from http://www.limat.org/data/research/Research%20Methodology.pdf

The Sims Studio. (2009). The Sims 3: Electronic Arts.

Thompson, J. J., Blair, M. R., & Henrey, A. J. (2014). Over the Hill at 24: Persistent Age-Related Cognitive-Motor Decline in Reaction Times in an Ecologically Valid Video Game Task Begins in Early Adulthood. *PLOS one, 9*(4).

Togelius, J., Preuss, M., Beume, N., Wessing, S., Hagelback, J., & Yannakakis, G. N. (2010). *Multiobjective exploration of the starcraft map space.* Paper presented at the Computational Intelligence and Games (CIG), Dublin.

Transmission Games. (2009). Ashes Cricket 2009: Codemasters

Trochim, W. M. K., & Donnelly, J. P. (2005). *Research methods: The concise knowledge base* (1st ed.): Atomic Dog

Turtle Rock Studios, & Valve Corporation. (2008). Left 4 Dead: Valve Corporation.

Ubisoft Montreal. (2002). Tom Clancy's Splinter Cell: Ubisoft.

Urbaniak, G. C., & Plous, S. (2008). Research Randomizer Retrieved 15th December, 2013, from http://www.randomizer.org/form.htm

Uriarte, A., & Ontañón, S. (2012). *Kiting in RTS games using influence maps.* Paper presented at the Eighth Artificial Intelligence and Interactive Digital Entertainment Conference.

Valve Corporation. (2011). Portal 2 Valve Corporation, Electronic Arts.

VanOrd, K. (2013). BioShock Infinite Review. *Gamespot Reviews* Retrieved 21st April, 2014, from http://www.gamespot.com/reviews/bioshock-infinite-review/1900-6405762/

Wade, B., Kipp, T., & Beach, E. (2010). Civilization V: 2K Games.

Wiegman, O., & van Schie, E. G. M. (1998). Video game playing and its relations with aggressive and prosocial behavior. *British Journal of Social Psychology, 37*, 367-378.

Wolf, M. J. P. (2002). *The Medium of the Video Game* (1st ed.). Austin: University of Texas Press.

Workman, R. (2010). Motion gaming review: Xbox vs. Wii vs. PS3 Retrieved 16th April, 2012, from http://www.nbcnews.com/id/37911691/ns/technology_and_science-games/t/motion-gaming-review-xbox-vs-wii-vs-ps/#.VEaXXSKUfj4

Wylie, G., & Allport, A. (2000). Task Switching and the measurement of "switch costs". *Psychological research, 63*(3-4), 212-233.

Zelazo, P. D., Carter, A., Reznick, J. S., & Frye, D. (1997). Early development of executive function: A problem-solving framework. *Review of general psychology, 1*(2), 198.

Zikmund, W. G. (2003). *Business Research Methods* (7th ed.). Mason Ohio: South-Western.

Appendices

Appendix A. Questionnaire

UNIVERSITY OF KWAZULU-NATAL
School of Information Systems &Technology

M Com Research Project
Researcher: Yusuf Ismail 0837910405 (yismail786@gmail.com)
Supervisor: Mr C. Blewett 0312602161 (blewett@ukzn.ac.za)

Research Office: Ms P Ximba 0312603587

Dear Respondent,

I, Yusuf Ismail am a M Com student in the School of Information Systems & Technology, at the University of KwaZulu-Natal. You have been selected to participate in a research project entitled Real Time Strategy (RTS) Games and Task Switching. The aim of this study is to assess the impact of RTS video games on task switching ability. Through your participation, I hope to gain a better understanding of this gaming genre's effects on multitasking skill. Should you meet the criteria for this experiment, you may be requested to perform multitasking related tests and undergo "training" in a RTS video game.

Your participation in this project is voluntary. You may refuse to participate or withdraw from the project at any time without any negative consequences. There will be no monetary gain from participating in this research project. Your responses will be treated in the utmost confidential manner. Confidentiality and anonymity of records identifying you as a participant will be maintained by the School of Information Systems & Technology, UKZN and will be disposed of once the study has been completed. If you have any questions or concerns about participating in this study, please contact me or my supervisor at the numbers listed above. It should take you about 10 minutes to complete the questionnaire. Your participation in this project is most appreciated and I hope you will take the time to complete this questionnaire.

Sincerely

Yusuf Ismail

CONSENT

By signing below, you hereby confirm that you understand the contents of this document, the nature of the research project and you consent to participating in the research project. You understand that you are at liberty to withdraw from this study at any time should you so desire, without any negative consequences.

-------------------------------- -----------------------------

Participant's Signature Date

THIS QUESTIONNAIRE CONSISTS OF **3 SECTIONS (A, B AND C) AND 8 NUMBERED PAGES**. PLEASE ENSURE YOU **ANSWER ALL SECTIONS**.

Section A

1) Your Name: ______________________________________
2) Surname: ____
3) Your Age: ________
4) Your Gender: ☐ Male ☐ Female
5) Your racial group

   ☐ Black ☐ Coloured ☐ Indian

   ☐ White ☐ Another group: ________________________

6) How many years have you been playing video games?

   ____

7) During an average week in the past 6 months how many hours did you spend playing video games?

   ____

Section B

For each video game category, please rate:

1. Your estimated EXPERTISE in that category (1 = beginner, 7 = expert) **(Circle the appropriate number)**
2. Your average HOURS PER WEEK in that category in the past **6 months**.

First-person shooters (E.g. Call of Duty, Battlefield, CounterStrike, Half-life, Unreal, BioShock, Halo, Dead Space, Left 4 Dead, Far Cry etc.)							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Third-person shooters (E.g. Gears of War, Grand Theft Auto, Metal Gear, God of War etc**.)**							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Role-Playing (E.g. The Witcher, The Elder Scrolls, Demons Souls, Fable, Final Fantasy etc.)							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Massively Multiplayer Online games (E.g. World of Warcraft, Lord of the Rings Online, Guild Wars, EVE Online etc.)							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Turn-based Strategy (E.g. Civilization, Heroes of Might and Magic etc.)							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Real-time Strategy (E.g. StarCraft, Age of Empires, Total War, Battle for Middle Earth, Warcraft Ladder etc.)							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Music (E.g. Dance Dance Revolution, Guitar Hero, Rock Band etc.)							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Simulation (E.g. SimCity, Flight Simulator, Airline Tycoon, Rollercoaster Tycoon etc.)							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Fighting Games (E.g. Soul Calibre, Mortal Kombat, Street Fighter etc.)							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Sports (E.g. Fifa 12, Pro Evolution Soccer 2012, Ashes 2010, Grand Turismo, Need for Speed etc.)							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Other (please specify games that don't fit into any other category e.g. phone games – Angry Birds, browser games - Farmville, etc.) ____							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Other (please specify games that don't fit into any other category e.g. phone games – Angry Birds, browser games - Farmville, etc.) ____							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Other (please specify games that don't fit into any other category e.g. phone games – Angry Birds, browser games - Farmville, etc.) ____							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Other (please specify games that don't fit into any other category e.g. phone games – Angry Birds, browser games - Farmville, etc.) ____							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Other (please specify games that don't fit into any other category e.g. phone games – Angry Birds, browser games - Farmville, etc.) ____							
Expertise:	1	2	3	4	5	6	7
Hours per week:							

Section C

Please indicate the time you spend for each activity listed below.

1) While you are studying or working **ALONE**, do you:

	Not at all	1-20% of the time	21-40% of the time	41-60% of the time	61-80% of the time	>80% of the time
Listen to music or the radio						
Eat and/or drink						
Check email on your PC or mobile device intermittently						
Use Facebook/Twitter or other social networking sites on your mobile device or PC intermittently						
Instant Messaging via BBM/Whatsapp/ iMessage/other						
Play video games on your PC or mobile device						
Other multitasking behaviour – please explain						
Other multitasking behaviour – please explain						

2) While you are studying or working **IN A GROUP**, do you:

	Not at all	1-20% of the time	21-40% of the time	41-60% of the time	61-80% of the time	>80% of the time
Listen to music or the radio						
Eat and/or drink						
Check email on your PC or mobile device intermittently						
Use Facebook/Twitter or other social networking sites on your mobile device or PC intermittently						
Instant Messaging via BBM/Whatsapp/ iMessage/other						
Play video games on your PC or mobile device						
Other multitasking behaviour – please explain						
Other multitasking behaviour – please explain						

3) While **DRIVING** do you: *(you make skip this question if you do not drive a motor vehicle)*

	Not at all	1-20% of the time	21-40% of the time	41-60% of the time	61-80% of the time	>80% of the time
Listen to music or the radio						
Switch Radio stations/change CD's						
Eat and/or drink						
Check email on your mobile device intermittently						
Text via BBM/Whatsapp/ iMessage/other						
Talk to a passenger						
Talk over your mobile device						
Use Facebook/Twitter or other social networking sites on your mobile device						
Play video games or other types of games (e.g. poker) on your mobile device						
Put make-up on/groom yourself						
Other multitasking behaviour – please explain						

END OF QUESTIONNAIRE – THANK YOU FOR YOUR TIME.

Appendix B. Statisticians letters

B1. Statistician A

Strictly Stats cc

CK 2011/007970/23

+27 82 459 9803

statsninja@gmail.com

16 October 2014

To whom it may concern

Please be advised that I have assisted Yusuf Ismail (student number 207511342**),** who is presently studying for a Master of Commerce, with the statistical analysis for his study.

Yours sincerely

M. Jamal

B2. Statistician B

Gill Hendry B.Sc. (Hons), M.Sc. (Wits)

Mathematical and Statistical Services

Cell: 083 300 9896

email : hendryfam@telkomsa.net

16 October 2014

To whom it may concern

Please be advised that I have assisted Yusuf Ismail (student number 207511342**),** who is presently studying for a Master of Commerce, with the statistical analysis for his study.

Yours sincerely

Gill Hendry (Mrs)

Appendix C. Gameplay modes of StarCraft

The RTS video game StarCraft can be in one of two gameplay modes at any given time. The first gameplay mode is introduced in the campaign (story mode) where the user interface involves the appearance of computer-controlled characters who engage in dialogue with each other before the player begins the story mode scenario. Although no challenges exist in this mode the characters function to "act" out the games story. This gameplay mode can be seen in figure C1 below.

Figure C1 – Gameplay mode of story mode in StarCraft

The second gameplay mode of StarCraft has been articulated thoroughly in section 2.4.1 (RTS video games under video game genres) of chapter two. The gameplay and the user interface of this second gameplay mode of StarCraft have been explained in detail in section 2.4.1. Figure 2.2 (RTS video games picture under video game genres) illustrates this second gameplay mode.

Appendix D. Other core mechanics of StarCraft

D1. The Design of units

- **Numerical attributes**

Numerical attributes are assigned to each unit type in RTS video games (E. Adams, 2009). Unit types begin with the values that they require for each attribute (E. Adams, 2009). These values change as units sustain damage or deplete energy (E. Adams, 2009). The numerical attributes that are assigned to units in StarCraft are listed and discussed below.

- **Hit points (HP)**

The health of units is measured in HP (E. Adams, 2009). This number is reduced as units sustain damage (E. Adams, 2009). When this number equals or is lower than zero the unit is destroyed and removed from the game world (E. Adams, 2009; Uriarte & Ontañón, 2012). Stronger units such as Zerg Ultralisks are robust and feature high health pools. In StarCraft the current armour level of the unit reduces incoming damage. Furthermore, all Protoss units possess shields which absorb all incoming damage first before HP is reduced.

- **Number of weapons available**

Each unit may have zero or more weapons equipped (E. Adams, 2009). Transportation units such as Terran Dropships are unarmed. Other units such as Protoss Scouts are equipped with air-to-air missiles and air-to-ground guns. Each weapon has its own characteristics and properties.

- **Attack range**

This is the maximum distance at which a unit can attack (E. Adams, 2009; Uriarte & Ontañón, 2012). Some units such as Zerg Zerglings are only capable of attacking adjacent units with their melee attacks. Some long ranged weapons such as Terran Siege Tanks in siege mode also include a minimum range. These weapons cannot fire on units that are closer than the minimum range.

- **Attack time**

Time that a unit takes to execute an attack (Uriarte & Ontañón, 2012).

- **Attack cooldown**

Minimum time between attacks (Uriarte & Ontañón, 2012). This value can change pending research upgrades or active spells. For example Terran marines can activate stimpacks (once researched) to reduce the time between their attacks, enabling to fire at a fast rate. Similarly, the Zerg Queen's ensnare spell can increase the time between enemy unit attacks.

- **Splash damage**

Some weapons types are capable of hitting multiple units (E. Adams, 2009). For example the Terran Siege Tank's weapon in siege mode enables it to hit multiple units in a small area.

- **Unit Size**

All units in StarCraft are small, medium or large in size. These sizes have ramifications on the amount of damage they receive from each damage type.

- **Damage type**

In StarCraft every weapon deals its damage in the form of concussive, normal or explosive damage. These types of damage do either reduced or full damage to the units they hit based on their size.

- **Energy**

Some units possess unique abilities and are granted energy. These abilities such as the ensnare spell possessed by Zerg Queens, can be used by consuming energy. Energy is replenished over time up to its maximum value.

- **Speed**

The top speed of a unit (Uriarte & Ontañón, 2012). This value can change pending upgrades. Protoss zealots with the movement speed upgrade are able to cover distances quickly making them more effective. Similarly, abilities such as the Zerg Queen's ensnare spell can reduce the movement speed of units.

- **Range of vision**

Each unit in StarCraft possess a range of vision value. The higher this value the further a unit as able to see into the fog of war (for a detailed explanation on the fog of war please refer to the finding hidden objects portion of gameplay challenges in section 2.6.1 of chapter two) (in most cases positioning units at higher altitudes grants them a better of range of vision (E. Adams, 2009). This value can also be altered. For example, the Terran medic is capable of blinding units which reduces their range of vision to the minimum value.

- **Acceleration/deceleration**

Time taken for a unit to reach top speed or time to come to a complete halt (E. Adams, 2009; Uriarte & Ontañón, 2012). Some units such as the Zerg Mutalisk require a few seconds to accelerate. Experienced players micro manage their Mutalisks keeping them moving (and at top speed) at all times to increase their mobility.

- **Population count**

This value displays the amount of free population each unit requires. Each unit consumes a portion of the population limit (maximum two hundred). Weaker units such as Terran Marines consume one supply whereas more expensive and stronger units such as Terran Battlecruisers consume six (for further discussion on population and its limits see figure 2.1 and section 2.6.1).

Figure C2 below highlights some of the attributes that have been explained.

Figure C2- Visible numerical attributes of a StarCraft unit (Protoss Arbiter)

Appendix E. Summary of statistical tests

The statistical tests conducted on the data collected in this study are listed and explained below.

- **Reliability analysis**

Cronbach's coefficient alphas were used to measure internal consistency reliability.

- **Factor analysis**

The purpose of factor analysis is to reduce the total number of variables and condense the data into a smaller number of factors that can be used for further analysis (Zikmund, 2003). Factor loading scores measure the strength of association for each statement on its corresponding factor. Furthermore explained variation measures how well each factor represents the variables that are associated with it.

- **Descriptive statistics**

These statistics included simple summaries about the sample and measures which describe trends and provides the opportunity to examine and explore individual variables at a time. This leads to a better understanding of the data and what the questionnaire respondents have to say about the topic under study.

- **Mann–Whitney U test**

The Mann–Whitney U test is a non-parametric statistical hypothesis test for assessing whether one of two samples of independent observations tends to have larger values than the other. It is one of the most well-known non-parametric significance tests.

- **Wilcoxon signed-rank test**

The Wilcoxon signed-rank test is a non-parametric statistical hypothesis test used when comparing two related samples, matched samples, or repeated measurements on a single sample to assess whether their population mean ranks differ (i.e. it's a paired difference test). It can be used as an alternative to the paired Student's t-test, t-test for matched pairs, or the t-test for dependent samples when the population cannot be assumed to be normally distributed.

- **Pearson Correlation**

Correlation between sets of data is a measure of how well they are related

- **Independent T-tests**

The independent samples t-test compares the mean scores of two groups drawn from independent samples (Keller & Warrack, 2000). This form of t-test is commonly used when there is no association between the two sets of scores or values that are being compared.

- **One-way Analysis of Variance (ANOVA)**

The purpose of an ANOVA is to test for significant differences between the means of multiple groups (Zikmund, 2003).The technique analyses the variance of the data to determine whether it can be inferred that the population means differ (Keller & Warrack, 2000).

- **Analysis of covariance (ANCOVA)**

ANCOVA evaluates whether population means of a dependent variable are equal across levels of a categorical independent variable, while statistically controlling for the effects of covariates (other continuous variables that are not of primary interest).

Appendix F. Reliability

F1. Video game expertise

Case Processing Summary

		N	%
Cases	Valid	34	100.0
	Excluded[a]	0	0.0
	Total	34	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.547	10

Item Statistics

	Mean	Std. Deviation	N
FPSexpertise	4.26	2.005	34
TPSexpertise	4.47	2.149	34
RPGexpertise	3.76	2.523	34
MMOexpertise	3.15	2.298	34
TBSexpertise	2.97	1.930	34
RTSexpertise	1.21	.914	34
MusicExpertise	1.76	1.776	34
SimExpertise	2.15	1.635	34
FightingExpertise	4.15	1.726	34
SportsExpertise	3.65	2.255	34

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
FPSexpertise	27.26	61.594	.338	.491
TPSexpertise	27.06	58.663	.394	.471
RPGexpertise	27.76	58.973	.282	.507
MMOexpertise	28.38	69.516	.038	.584
TBSexpertise	28.56	59.951	.421	.468
RTSexpertise	30.32	69.922	.360	.515
MusicExpertise	29.76	68.185	.168	.538
SimExpertise	29.38	67.698	.219	.526
FightingExpertise	27.38	65.031	.296	.506
SportsExpertise	27.88	69.258	.051	.578

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
31.53	76.257	8.733	10

F2: Section C1

Case Processing Summary

		N	%
Cases	Valid	34	100.0
	Excluded[a]	0	0.0
	Total	34	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.675	6

Item Statistics

	Mean	Std. Deviation	N
SectionC1.1	2.65	1.807	34
SectionC1.2	2.82	1.029	34
SectionC1.3	2.91	1.422	34
SectionC1.4	3.00	1.706	34
SectionC1.5	4.15	1.579	34
SectionC1.6	2.59	1.459	34

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
SectionC1.1	15.47	24.075	.248	.699
SectionC1.2	15.29	28.032	.243	.678
SectionC1.3	15.21	23.623	.441	.623
SectionC1.4	15.12	19.925	.585	.562
SectionC1.5	13.97	21.908	.497	.600
SectionC1.6	15.53	23.287	.449	.619

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
18.12	31.743	5.634	6

F3: Section C2

Case Processing Summary

		N	%
Cases	Valid	34	100.0
	Excluded[a]	0	0.0
	Total	34	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.811	6

Item Statistics

	Mean	Std. Deviation	N
SectionC2.1	1.47	.929	34
SectionC2.2	2.62	1.101	34
SectionC2.3	2.15	1.351	34
SectionC2.4	2.15	1.520	34
SectionC2.5	3.03	1.487	34
SectionC2.6	1.65	1.178	34

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
SectionC2.1	11.59	27.704	.171	.846
SectionC2.2	10.44	23.102	.559	.785
SectionC2.3	10.91	21.053	.594	.776
SectionC2.4	10.91	17.598	.810	.717
SectionC2.5	10.03	19.181	.679	.755
SectionC2.6	11.41	22.128	.607	.774

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
13.06	30.239	5.499	6

F4: Section C3

Case Processing Summary

		N	%
Cases	Valid	32	94.1
	Excluded[a]	2	5.9
	Total	34	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.813	10

Item Statistics

	Mean	Std. Deviation	N
SectionC3.1	5.13	1.100	32
SectionC3.2	3.50	1.934	32
SectionC3.3	2.56	1.343	32
SectionC3.4	1.38	.976	32
SectionC3.5	2.72	1.708	32
SectionC3.6	4.25	1.459	32
SectionC3.7	2.41	1.500	32
SectionC3.8	1.44	1.268	32
SectionC3.9	1.09	.530	32
SectionC3.10	1.28	.958	32

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
SectionC3.1	20.63	58.887	.369	.808
SectionC3.2	22.25	52.581	.356	.824
SectionC3.3	23.19	53.254	.575	.787
SectionC3.4	24.38	56.758	.586	.791
SectionC3.5	23.03	50.354	.538	.792
SectionC3.6	21.50	59.032	.230	.826
SectionC3.7	23.34	50.362	.644	.777
SectionC3.8	24.31	50.415	.794	.763
SectionC3.9	24.66	60.362	.689	.798
SectionC3.10	24.47	56.386	.627	.788

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
25.75	66.323	8.144	10

Appendix G. Validity

G1. Video game expertise

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
FPSexpertise	4.26	2.005	34
TPSexpertise	4.47	2.149	34
RPGexpertise	3.76	2.523	34
MMOexpertise	3.15	2.298	34
TBSexpertise	2.97	1.930	34
RTSexpertise	1.21	.914	34
MusicExpertise	1.76	1.776	34
SimExpertise	2.15	1.635	34
FightingExpertise	4.15	1.726	34
SportsExpertise	3.65	2.255	34

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.512
Bartlett's Test of Sphericity	Approx.Chi-Square	82.305
	df	45
	Sig.	.001

Communalities

	Initial	Extraction
FPSexpertise	1.000	.566
TPSexpertise	1.000	.668
RPGexpertise	1.000	.073
MMOexpertise	1.000	.014
TBSexpertise	1.000	.310
RTSexpertise	1.000	.124
MusicExpertise	1.000	.189
SimExpertise	1.000	.278
FightingExpertise	1.000	.175
SportsExpertise	1.000	.000

Extraction Method: Principal Component Analysis.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.397	23.970	23.970	2.397	23.970	23.970
2	1.793	17.933	41.903			
3	1.687	16.866	58.768			
4	1.119	11.191	69.959			
5	.808	8.079	78.038			
6	.709	7.088	85.126			
7	.571	5.709	90.835			
8	.474	4.743	95.578			
9	.277	2.768	98.346			
10	.165	1.654	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
FPSexpertise	.752
TPSexpertise	.817
RPGexpertise	.270
MMOexpertise	-.118
TBSexpertise	.557
RTSexpertise	.352
MusicExpertise	.434
SimExpertise	.527
FightingExpertise	.418
SportsExpertise	.021

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

G2. Section C1

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
SectionC1.1	2.65	1.807	34
SectionC1.2	2.82	1.029	34
SectionC1.3	2.91	1.422	34
SectionC1.4	3.00	1.706	34
SectionC1.5	4.15	1.579	34
SectionC1.6	2.59	1.459	34

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.587
Bartlett's Test of Sphericity	Approx. Chi-Square	41.359
	df	15
	Sig.	.000

Communalities

	Initial	Extraction
SectionC1.1	1.000	.154
SectionC1.2	1.000	.218
SectionC1.3	1.000	.370
SectionC1.4	1.000	.658
SectionC1.5	1.000	.575
SectionC1.6	1.000	.400

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.374	39.570	39.570	2.374	39.570	39.570
2	1.264	21.063	60.632			
3	.915	15.258	75.890			
4	.640	10.671	86.562			
5	.538	8.967	95.529			
6	.268	4.471	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
SectionC1.1	.392
SectionC1.2	.466
SectionC1.3	.608
SectionC1.4	.811
SectionC1.5	.758
SectionC1.6	.633

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

G3. Section C2

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
SectionC2.1	1.47	.929	34
SectionC2.2	2.62	1.101	34
SectionC2.3	2.15	1.351	34
SectionC2.4	2.15	1.520	34
SectionC2.5	3.03	1.487	34
SectionC2.6	1.65	1.178	34

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.796
Bartlett's Test of Sphericity	Approx. Chi-Square	73.284
	df	15
	Sig.	.000

Communalities

	Initial	Extraction
SectionC2.1	1.000	.067
SectionC2.2	1.000	.480
SectionC2.3	1.000	.563
SectionC2.4	1.000	.808
SectionC2.5	1.000	.680
SectionC2.6	1.000	.546

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.145	52.415	52.415	3.145	52.415	52.415
2	1.179	19.645	72.060			
3	.561	9.344	81.403			
4	.525	8.751	90.154			
5	.376	6.267	96.421			
6	.215	3.579	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
SectionC2.1	.260
SectionC2.2	.693
SectionC2.3	.750
SectionC2.4	.899
SectionC2.5	.825
SectionC2.6	.739

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

G4. Section C3

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
SectionC3.1	5.13	1.100	32
SectionC3.2	3.50	1.934	32
SectionC3.3	2.56	1.343	32
SectionC3.4	1.38	.976	32
SectionC3.5	2.72	1.708	32
SectionC3.6	4.25	1.459	32
SectionC3.7	2.41	1.500	32
SectionC3.8	1.44	1.268	32
SectionC3.9	1.09	.530	32
SectionC3.10	1.28	.958	32

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.723
Bartlett's Test of Sphericity	Approx. Chi-Square	187.863
	df	45
	Sig.	.000

Communalities

	Initial	Extraction
SectionC3.1	1.000	.145
SectionC3.2	1.000	.151
SectionC3.3	1.000	.480
SectionC3.4	1.000	.598
SectionC3.5	1.000	.455
SectionC3.6	1.000	.082
SectionC3.7	1.000	.538
SectionC3.8	1.000	.735
SectionC3.9	1.000	.729
SectionC3.10	1.000	.665

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.578	45.783	45.783	4.578	45.783	45.783
2	1.531	15.306	61.089			
3	1.329	13.289	74.377			
4	.902	9.018	83.395			
5	.592	5.916	89.311			
6	.322	3.225	92.536			
7	.307	3.070	95.606			
8	.225	2.252	97.858			
9	.164	1.641	99.499			
10	.050	.501	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
SectionC3.1	.381
SectionC3.2	.389
SectionC3.3	.693
SectionC3.4	.773
SectionC3.5	.675
SectionC3.6	.286
SectionC3.7	.733
SectionC3.8	.858
SectionC3.9	.854
SectionC3.10	.815

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Appendix H. Switch Costs

H1. Summary of statistical tests

	Switch Cost Time 1	Switch Cost Time 2	Test Used	p-value	Significance
Whole Group	[a] 158.027	[b] 114.532	Non-Parametric Wilcoxon Signed Ranks Test *(a - b)*	0.059	Not Significant
Control Group	[c] 155.159	[d] 122.437	Non-Parametric Wilcoxon Signed Ranks Test *(c - d)*	0.586	Not Significant
Experimental Group	[e] 160.895	[f] 106.626	Non-Parametric Wilcoxon Signed Ranks Test *(e - f)*	0.025	**Significant**

	Switch Cost Time 1	Switch Cost Time 2
Test Used	Non-Parametric Mann-Whitney Test *(c-e)*	Non-Parametric Mann-Whitney Test *(d-f)*
p-value	0.796	0.480
Significance	Not Significant	Not Significant

H2. Switch cost pre-training: whole sample

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
SwitchCostTime1	34	158.02656247	127.762791680	-43.744318	492.232143
Group	34	1.50	.508	1	2

H3. Switch cost pre-training: control vs. experimental

Mann-Whitney Test

Ranks

Group		N	Mean Rank	Sum of Ranks
SwitchCostTime1	Control	17	17.06	290.00
	Experimental	17	17.94	305.00
	Total	34		

Test Statistics[a]

	SwitchCostTime1
Mann-Whitney U	137.000
Wilcoxon W	290.000
Z	-.258
Asymp. Sig. (2-tailed)	.796
Exact Sig. [2*(1-tailed Sig.)]	.812[b]

a. Grouping Variable: Group

b. Not corrected for ties.

H4. Switch cost post-training: whole sample

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
SwitchCostTime2	34	114.53157691	97.328506078	-25.714286	330.933743
Group	34	1.50	.508	1	2

H5. Switch cost post-training: control vs. experimental

Mann-Whitney Test

Ranks

Group		N	Mean Rank	Sum of Ranks
SwitchCostTime2	Control	17	18.71	318.00
	Experimental	17	16.29	277.00
	Total	34		

Test Statistics[a]

	SwitchCostTime2
Mann-Whitney U	124.000
Wilcoxon W	277.000
Z	-.706
Asymp. Sig. (2-tailed)	.480
Exact Sig. [2*(1-tailed Sig.)]	.496[b]

H6. Switch cost time pre and post-training: whole sample

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles 25th	Percentiles 50th (Median)	Percentiles 75th
SwitchCostTime1	34	158.02656247	127.762791680	-43.744318	492.232143	61.48350150	143.71541500	254.53884600
SwitchCostTime2	34	114.53157691	97.328506078	-25.714286	330.933743	38.31874925	89.62994900	175.78106800

H7. Switch cost pre-training vs. switch cost post-training: whole sample

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
SwitchCostTime2 - SwitchCostTime1	Negative Ranks	23[a]	17.74	408.00
	Positive Ranks	11[b]	17.00	187.00
	Ties	0[c]		
	Total	34		

a. SwitchCostTime2 < SwitchCostTime1

b. SwitchCostTime2 > SwitchCostTime1

c. SwitchCostTime2 = SwitchCostTime1

Test Statistics[a]

	SwitchCostTime2 - SwitchCostTime1
Z	-1.889[b]
Asymp. Sig. (2-tailed)	.059

H8. Switch cost pre and post-training: control group

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
SwitchCostTime1	17	155.15858612	132.179680043	-32.023505	492.232143	52.63167050	147.39333000	211.25637350
SwitchCostTime2	17	122.43749253	101.237940650	-10.787334	330.933743	60.31763900	92.09000000	156.39659500

H9. Switch cost pre-training vs. post-training: control group

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
SwitchCostTime2 - SwitchCostTime1	Negative Ranks	10[a]	8.80	88.00
	Positive Ranks	7[b]	9.29	65.00
	Ties	0[c]		
	Total	17		

a. SwitchCostTime2 < SwitchCostTime1

b. SwitchCostTime2 > SwitchCostTime1

c. SwitchCostTime2 = SwitchCostTime1

Test Statistics[a]

	SwitchCostTime2 - SwitchCostTime1
Z	-.544[b]
Asymp. Sig. (2-tailed)	.586

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

H10. Switch cost pre and post-training: experimental group

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
SwitchCostTime1	17	160.89453882	127.192466385	-43.744318	343.168328	65.41306800	140.03750000	287.88303800
SwitchCostTime2	17	106.62566129	95.685881945	-25.714286	272.209273	26.31749400	77.32993200	206.90932100

H11. Switch cost pre-training vs. switch cost post-training: experimental group

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
SwitchCostTime 2 - SwitchCostTime 1	Negative Ranks	13[a]	9.54	124.00
	Positive Ranks	4[b]	7.25	29.00
	Ties	0[c]		
	Total	17		

a. SwitchCostTime2 < SwitchCostTime1

b. SwitchCostTime2 > SwitchCostTime1

c. SwitchCostTime2 = SwitchCostTime1

Test Statistics[a]

	SwitchCostTime2 - SwitchCostTime1
Z	-2.249[b]
Asymp. Sig. (2-tailed)	.025

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

H12. Paired sample T test: control group

		Mean	N	Std. Deviation
Pair 1	Switch cost pre-training	1.55158586E2	17	1.321796800E2
	Switch Cost on post-training test	1.22437493E2	17	1.012379406E2

Paired Samples Test[a]

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Switch cost pre-training - Switch Cost on post-training test	3.272109359E1	1.687541346E2	4.092888951E1	-5.404427617E1	1.194864633E2	.799	16	.436

a. Control or experimental = Control Group

H13. Paired sample T test: experimental group

		Mean	N	Std. Deviation
Pair 1	Switch cost pre-training	1.60894539E2	17	1.271924664E2
	Switch Cost on post-training test	1.06625661E2	17	9.568588194E1

Paired Samples Test[a]

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Switch cost pre-training - Switch Cost on post-training test	5.426887753E1	1.035606666E2	2.511715100E1	1.022896032	1.075148590E2	2.161	16	.046

a. Control or experimental = Experimental Group

Appendix I. Proportional switch costs

I1. Summary of statistical tests

	Proportional Switch Cost 1	Proportional Switch Cost 2	Test Used	p-value	Significance
Whole Group	[a] 15.851	[b] 12.413	Non-Parametric Wilcoxon Signed Ranks Test *(a - b)*	0.203	Not Significant
Control Group	[c] 15.559	[d] 13.557	Non-Parametric Wilcoxon Signed Ranks Test *(c - d)*	0.906	Not Significant
Experimental Group	[e] 16.144	[f] 11.270	Non-Parametric Wilcoxon Signed Ranks Test *(e - f)*	0.035	**Significant**
Test Used	Non-Parametric Mann-Whitney Test *(c-e)*	Non-Parametric Mann-Whitney Test *(d-f)*			
p-value	0.418	0.593			
Significance	Not Significant	Not Significant			

I2. Proportional switch cost pre-training: whole sample

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
ProportionalSwitchCost1	34	15.85146326933680	14.756521287460000	-3.985276103640	75.888555482752	6.35560596550428	13.07984464043340	23.73295589462290
Group	34	1.50	.508	1	2	1.00	1.50	2.00

I3. Proportional switch cost pre-training: control vs. experimental

Mann-Whitney Test

Ranks

Group		N	Mean Rank	Sum of Ranks
ProportionalSwitchCost1	Control	17	16.12	274.00
	Experimental	17	18.88	321.00
	Total	34		

Test Statistics[a]

	ProportionalSwitchCost1
Mann-Whitney U	121.000
Wilcoxon W	274.000
Z	-.809
Asymp. Sig. (2-tailed)	.418
Exact Sig. [2*(1-tailed Sig.)]	.433[b]

a. Grouping Variable: Group

b. Not corrected for ties.

I4. Proportional switch cost post-training: whole sample

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
ProportionalSwitchCost2	34	12.41340105513810	10.531366550491200	-1.944789605760	35.294290392298	3.92247051462787	11.15454972188400	19.95851023123580
Group	34	1.50	.508	1	2	1.00	1.50	2.00

I5. Proportional switch cost post-training: control vs. experimental group

Mann-Whitney Test

Ranks

Group		N	Mean Rank	Sum of Ranks
ProportionalSwitchCost2	Control	17	18.41	313.00
	Experimental	17	16.59	282.00
	Total	34		

Test Statistics[a]

	ProportionalSwitchCost2
Mann-Whitney U	129.000
Wilcoxon W	282.000
Z	-.534
Asymp. Sig. (2-tailed)	.593
Exact Sig. [2*(1-tailed Sig.)]	.610[b]

a. Grouping Variable: Group

b. Not corrected for ties.

I6. Proportional switch costs pre and post-training: whole sample

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
ProportionalSwitchCost1	34	15.85146326933680	14.756521287460000	-3.985276103640	75.888555482752	6.35560596550428	13.07984464043340	23.73295589462290
ProportionalSwitchCost2	34	12.41340105513810	10.531366550491200	-1.944789605760	35.294290392298	3.92247051462787	11.15454972188400	19.95851023123580

I7. Proportional switch cost pre-training vs. proportional switch cost post training: whole sample

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
ProportionalSwitchCost2 - ProportionalSwitchCost1	Negative Ranks	21[a]	17.71	372.00
	Positive Ranks	13[b]	17.15	223.00
	Ties	0[c]		
	Total	34		

a. ProportionalSwitchCost2 < ProportionalSwitchCost1

b. ProportionalSwitchCost2 > ProportionalSwitchCost1

c. ProportionalSwitchCost2 = ProportionalSwitchCost1

Test Statistics[a]

	ProportionalSwitchCost2 - ProportionalSwitchCost1
Z	-1.274[b]
Asymp. Sig. (2-tailed)	.203

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

I8. Proportional switch costs pre and post-training: control group

Descriptive Statistics

						Percentiles		
	N	**Mean**	**Std. Deviation**	**Minimum**	**Maximum**	**25th**	**50th (Median)**	**75th**
ProportionalSwitchCost1	17	15.558967410120 0	17.338247196770600	-3.985276103640	75.888555482752	5.74676918324287	12.35042864125580	18.89654734728740
ProportionalSwitchCost2	17	13.557200706200 5 0	11.799428260127200	-1.524054769230	35.294290392298	4.52336143668712	11.86393269623570	19.49633032641230

I9. Proportional switch cost pre-training vs. proportional switch cost post-training: control group

Wilcoxon Signed Ranks Test

Ranks

		N	**Mean Rank**	**Sum of Ranks**
ProportionalSwitchCost2 - ProportionalSwitchCost1	Negative Ranks	9[a]	8.22	74.00
	Positive Ranks	8[b]	9.88	79.00
	Ties	0[c]		
	Total	17		

a. ProportionalSwitchCost2 < ProportionalSwitchCost1

b. ProportionalSwitchCost2 > ProportionalSwitchCost1

c. ProportionalSwitchCost2 = ProportionalSwitchCost1

Test Statistics[a]

	ProportionalSwitchCost2 - ProportionalSwitchCost1
Z	-.118[b]
Asymp. Sig. (2-tailed)	.906

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

I10. Proportional switch costs pre and post-training: experimental group

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles 25th	50th (Median)	75th
ProportionalSwitchCost1	17	16.143959128553500	12.178789176520300	-3.435473852648	35.996552851357	7.07597829163583	17.97307718324720	27.69502931313370
ProportionalSwitchCost2	17	11.269601404075600	9.313679223365930	-1.944789605760	30.203924413559	3.73880012778113	9.37684310058650	20.38580692311030

I11. Proportional switch cost pre-training vs. proportional switch cost post-training: experimental group

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
ProportionalSwitchCost2 - ProportionalSwitchCost1	Negative Ranks	12[a]	10.08	121.00
	Positive Ranks	5[b]	6.40	32.00
	Ties	0[c]		
	Total	17		

a. ProportionalSwitchCost2 < ProportionalSwitchCost1

b. ProportionalSwitchCost2 > ProportionalSwitchCost1

c. ProportionalSwitchCost2 = ProportionalSwitchCost1

Test Statistics[a]

	ProportionalSwitchCost2 - ProportionalSwitchCost1
Z	-2.107[b]
Asymp. Sig. (2-tailed)	.035

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

I12. ANCOVA on proportional switch costs

Tests of Between-Subjects Effects

Dependent Variable:Proportional switch cost post-training

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	79.056[a]	2	39.528	.342	.713	.022
Intercept	1987.780	1	1987.780	17.208	.000	.357
ProportionalSwitchCost1	34.574	1	34.574	.299	.588	.010
Group	46.055	1	46.055	.399	.532	.013
Error	3580.964	31	115.515			
Total	8899.165	34				
Corrected Total	3660.019	33				

a. R Squared = .022 (Adjusted R Squared = -.042)

Parameter Estimates

Dependent Variable: Proportional switch cost post-training

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Partial Eta Squared
Intercept	10.150	3.315	3.062	.005	3.389	16.910	.232
ProportionalSwitchCost1	.069	.127	.547	.588	-.189	.328	.010
[Group=1]	2.328	3.687	.631	.532	-5.192	9.848	.013
[Group=2]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Appendix J. Net errors

J1. Summary of statistical tests

	Net Errors 1	Net Errors 2	Test Used	p-value	Significance
Whole Group	[a] 0.101	[b] 0.103	Non-Parametric Wilcoxon Signed Ranks Test *(a - b)*	0.888	Not Significant
Control Group	[c] 0.109	[d] 0.118	Non-Parametric Wilcoxon Signed Ranks Test *(c - d)*	0.755	Not Significant
Experimental Group	[e] 0.092	[f] 0.088	Non-Parametric Wilcoxon Signed Ranks Test *(e - f)*	0.981	Not Significant
Test Used	Non-Parametric Mann-Whitney Test *(c-e)*	Non-Parametric Mann-Whitney Test *(d-f)*			
p-value	0.389	0.427			
Significance	Not Significant	Not Significant			

J2. Net errors pre-training: whole sample

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Neterrors1	34	.1007	.08054	0.00	.29	.0400	.0800	.1500
Group	34	1.50	.508	1	2	1.00	1.50	2.00

J3. Net errors pre-training: control vs. experimental group

Mann-Whitney Test

Ranks

Group		N	Mean Rank	Sum of Ranks
Neterrors1	Control	17	18.97	322.50
	Experimental	17	16.03	272.50
	Total	34		

Test Statistics[a]

	Neterrors1
Mann-Whitney U	119.500
Wilcoxon W	272.500
Z	-.862
Asymp. Sig. (2-tailed)	.389
Exact Sig. [2*(1-tailed Sig.)]	.394[b]

a. Grouping Variable: Group

b. Not corrected for ties.

J4. Net errors post-training: whole sample

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
NetErrors2	34	.103	.0761	0.0	.3	.030	.100	.153
Group	34	1.50	.508	1	2	1.00	1.50	2.00

J5. Net errors post-training: control vs. experimental group

Mann-Whitney Test

Ranks

Group		N	Mean Rank	Sum of Ranks
NetErrors2	Control	17	18.85	320.50
	Experimental	17	16.15	274.50
	Total	34		

Test Statistics[a]

	NetErrors2
Mann-Whitney U	121.500
Wilcoxon W	274.500
Z	-.794
Asymp. Sig. (2-tailed)	.427
Exact Sig. [2*(1-tailed Sig.)]	.433[b]

a. Grouping Variable: Group

b. Not corrected for ties.

J6. Net errors pre and post-training: whole sample

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Neterrors1	34	.1007	.08054	0.00	.29	.0400	.0800	.1500
NetErrors2	34	.103	.0761	0.0	.3	.030	.100	.153

J7. Net errors pre-training: vs. net errors post-training: whole sample

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
NetErrors2 - Neterrors1	Negative Ranks	19[a]	14.29	271.50
	Positive Ranks	13[b]	19.73	256.50
	Ties	2[c]		
	Total	34		

a. NetErrors2 < Neterrors1

b. NetErrors2 > Neterrors1

c. NetErrors2 = Neterrors1

Test Statistics[a]

	NetErrors2 - Neterrors1
Z	-.140[b]
Asymp. Sig. (2-tailed)	.888

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

J8. Net errors pre and post-training: control group

Descriptive Statistics

						Percentiles		
	N	Mean	Std. Deviation	Minimum	Maximum	25th	50th (Median)	75th
Neterrors1	17	.1090	.07769	0.00	.26	.0359	.1000	.1600
NetErrors2	17	.118	.0900	0.0	.3	.030	.110	.215

J9. Net errors pre-training vs. net errors post-training: control group

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
NetErrors2 - Neterrors1	Negative Ranks	10[a]	6.55	65.50
	Positive Ranks	5[b]	10.90	54.50
	Ties	2[c]		
	Total	17		

a. NetErrors2 < Neterrors1

b. NetErrors2 > Neterrors1

c. NetErrors2 = Neterrors1

Test Statistics[a]

	NetErrors2 - Neterrors1
Z	-.313[b]
Asymp. Sig. (2-tailed)	.755

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

J10. Net errors pre-training and post-training: experimental group

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Neterrors1	17	.0924	.08482	0.00	.29	.0400	.0600	.1100
NetErrors2	17	.088	.0580	0.0	.2	.035	.090	.130

J11. Net errors pre-training vs. net errors post-training: experimental group

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
NetErrors2 - Neterrors1	Negative Ranks	9[a]	8.56	77.00
	Positive Ranks	8[b]	9.50	76.00
	Ties	0[c]		
	Total	17		

a. NetErrors2 < Neterrors1

b. NetErrors2 > Neterrors1

c. NetErrors2 = Neterrors1

Test Statistics[a]

	NetErrors2 - Neterrors1
Z	-.024[b]
Asymp. Sig. (2-tailed)	.981

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

J12. ANCOVA on Error rates

Tests of Between-Subjects Effects

Dependent Variable: Net errors for post-training test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.035[a]	2	.017	3.457	.044	.182
Intercept	.058	1	.058	11.564	.002	.272
Neterrors1	.027	1	.027	5.397	.027	.148
Group	.005	1	.005	.962	.334	.030
Error	.156	31	.005			
Total	.554	34				
Corrected Total	.191	33				

a. R Squared = .182 (Adjusted R Squared = .130)

Parameter Estimates

Dependent Variable: Net errors for post-training test

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	.055	.022	2.466	.019	.010	.101	.164
Neterrors1	.359	.154	2.323	.027	.044	.673	.148
[Group=1]	.024	.024	.981	.334	-.026	.074	.030
[Group=2]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Appendix K. Switch costs and net errors as one measure

K1. Correlations between pre and post switch costs with errors

Correlations

		Switch cost pre-training	Net errors for pre-training test
Switch cost pre-training	Pearson Correlation	1	.058
	Sig. (2-tailed)		.743
	N	34	34
Net errors for pre-training test	Pearson Correlation	.058	1
	Sig. (2-tailed)	.743	
	N	34	34

Correlations[a]

		Switch Cost on post-training test	Net errors for post-training test
Switch Cost on post-training test	Pearson Correlation	1	.194
	Sig. (2-tailed)		.457
	N	17	17
Net errors for post-training test	Pearson Correlation	.194	1
	Sig. (2-tailed)	.457	
	N	17	17

a. Control/experimental group = Control Group

Correlations[a]

		Switch Cost on post-training test	Net errors for post-training test
Switch Cost on post-training test	Pearson Correlation	1	-.331
	Sig. (2-tailed)		.195
	N	17	17
Net errors for post-training test	Pearson Correlation	-.331	1
	Sig. (2-tailed)	.195	
	N	17	17

a. Control/experimental group = Experimental Group

K2. ANCOVA: Change in time/change in error measure

Parameter Estimates

Dependent Variable: change_time

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Partial Eta Squared
Intercept	54.713	34.876	1.569	.127	-16.514	125.940	.076
[Group=1] * change_errors	228.227	376.076	.607	.549	-539.822	996.276	.012
[Group=2] * change_errors	-107.860	459.583	-.235	.816	-1046.453	830.733	.002
[Group=1]	-19.891	49.408	-.403	.690	-120.795	81.013	.005
[Group=2]	0[a]	.	.	.	.	.	.
change_errors	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

K3. Without interaction

Parameter Estimates

Dependent Variable: change_time

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	53.884	34.461	1.564	.128	-16.400	124.169	.073
change_errors	93.436	287.842	.325	.748	-493.620	680.493	.003
[Group=1]	-20.303	48.858	-.416	.681	-119.949	79.343	.006
[Group=2]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

K4. Old pre and post time variables with change in errors as a covariate

Parameter Estimates

Dependent Variable: Switch cost on post-training test

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	75.211	31.723	2.371	.024	10.423	139.999	.158
SwitchCostTime1	.199	.132	1.509	.142	-.071	.469	.071
change_errors	-162.977	196.591	-.829	.414	-564.470	238.515	.022
[Group=1]	14.784	33.325	.444	.660	-53.274	82.842	.007
[Group=2]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

K5. Without change in errors

Parameter Estimates

Dependent Variable: Switch Cost on post-training test

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	73.510	31.497	2.334	.026	9.272	137.748	.149
SwitchCostTime1	.206	.131	1.568	.127	-.062	.474	.073
[Group=1]	16.992	33.050	.514	.611	-50.413	84.398	.008
[Group=2]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Appendix L. Reaction times

Tests of Between-Subjects Effects

Dependent Variable: Reaction time for repeated trials on post-training test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	936121.215[a]	2	468060.607	12.262	.000	.442
Intercept	15190.641	1	15190.641	.398	.533	.013
TaskRepeatTime1	929805.272	1	929805.272	24.358	.000	.440
Group	7940.541	1	7940.541	.208	.652	.007
Error	1183326.149	31	38171.811			
Total	3.292E7	34				
Corrected Total	2119447.364	33				

a. R Squared = .442 (Adjusted R Squared = .406)

Parameter Estimates

Dependent Variable:Reaction time for repeated trials on post-training test

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	94.414	177.414	.532	.598	-267.423	456.252	.009
TaskRepeatTime1	.818	.166	4.935	.000	.480	1.156	.440
[Group=1]	30.566	67.017	.456	.652	-106.116	167.248	.007
[Group=2]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Tests of Between-Subjects Effects

Dependent Variable: Reaction time for switched trials on post-training test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1.702E6	2	851151.337	29.603	.000	.656
Intercept	92.646	1	92.646	.003	.955	.000
TaskSwitchTime1	1686534.366	1	1686534.366	58.658	.000	.654
Group	22786.269	1	22786.269	.793	.380	.025
Error	891314.002	31	28752.065			
Total	4.126E7	34				
Corrected Total	2593616.675	33				

a. R Squared = .656 (Adjusted R Squared = .634)

Parameter Estimates

Dependent Variable:Reaction time for switched trials on post-training test

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	-17.877	144.723	-.124	.902	-313.042	277.288	.000
TaskSwitchTime1	.891	.116	7.659	.000	.654	1.129	.654
[Group=1]	51.786	58.171	.890	.380	-66.855	170.427	.025
[Group=2]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Appendix M. Demographics

M1. Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	28	82.4	82.4	82.4
	Female	6	17.6	17.6	100.0
	Total	34	100.0	100.0	

M2. Race

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Coloured	2	5.9	5.9	5.9
	Indian	31	91.2	91.2	97.1
	White	1	2.9	2.9	100.0
	Total	34	100.0	100.0	

M3. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Age	34	19	33	23.79	3.346
How many years have you been playing video games?	34	10	22	16.00	4.045
During an average week in the past 6 months how many hours did you spend playing video games?	34	6	35	11.82	7.554
Valid N (listwise)	34				

Appendix N. Gaming habits

N1. Expertise

	N	Mean	Std. Deviation
FPSexpertise	34	4.26	2.005
TPSexpertise	34	4.47	2.149
RPGexpertise	34	3.76	2.523
MMOexpertise	34	3.15	2.298
TBSexpertise	34	2.97	1.930
RTSexpertise	34	1.21	.914
MusicExpertise	34	1.76	1.776
SimExpertise	34	2.15	1.635
FightingExpertise	34	4.15	1.726
SportsExpertise	34	3.65	2.255

	fours - FPSexpertise	fours - TPSexpertise	fours - RPGexpertise	fours - MMOexpertise	fours - TBSexpertise
Z	-.735[a]	-1.214[a]	-.931[b]	**-2.297**[b]	**-2.918**[b]
Asymp. Sig. (2-tailed)	.463	.225	.352	**.022**	**.004**

	fours - RTSexpertise	fours - MusicExpertise	fours - SimExpertise	fours - FightingExpertise	fours - SportsExpertise
Z	**-5.646**[b]	**-4.656**[b]	**-4.496**[b]	-.387[a]	-1.137[b]
Asymp. Sig. (2-tailed)	**.000**	**.000**	**.000**	.698	.255

N2. Hours per week

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
FPS usage per week	34	.0	10.0	2.706	2.5379
TPS usage per week	34	.0	10.0	2.853	2.7840
RPG usage per week	34	.0	10.0	2.353	3.0240
MMO usage per week	34	.0	30.0	3.176	6.4407
TBS usage per week	34	.0	6.0	.868	1.3445
RTS usage per week	34	.0	4.0	.147	.7020
Music usage per week	34	.0	5.0	.324	.9445
Simulation usage per week	34	.0	4.0	.618	1.1551
Fighting usage per week	34	.0	4.0	1.691	1.4565
Sports usage per week	34	.0	8.0	2.191	2.3420
Valid N (listwise)	34				

N3. Other games that subjects reported under other:

	N	Mean	Std. Deviation
Angry Birds expertise	7	4.86	1.676
Candy Crush expertise	9	5.78	1.202
Drag Racing expertise	2	5.50	2.121
Hidden Object expertise	1[a]	5.00	.
Farmville expertise	1[a]	5.00	.
Stick Cricket	2	6.50	.707
Poker expertise	2	4.50	.707
Snow Bros expertise	1[a]	7.00	.
Super Mario Brothers expertise	1[a]	7.00	.
Jetpack Joyride expertise	1[a]	7.00	.
Subway Surfer expertise	1[a]	7.00	.
Threes expertise	1[a]	7.00	.
ChessPro expertise	1[a]	5.00	.
Minion Rush expertise	1[a]	5.00	.
Arcade Shooter expertise	1[a]	6.00	.
Clash of Clans expertise	2	6.50	.707
HobbitKom expertise	1[a]	4.00	.
Flappy Bird expertise	1[a]	3.00	.
Minecraft expertise	1[a]	5.00	.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Angry Birds usage per week	7	.0	4.0	1.929	1.3671
Candy Crush usage per week	9	.0	7.0	2.889	2.1473
Drag Racing usage per week	2	4.0	20.0	12.000	11.3137
Hidden Object usage per week	1	3.0	3.0	3.000	.
Farmville usage per week	1	3.0	3.0	3.000	.
Stick Cricket usage per week	2	3.0	3.0	3.000	.0000
Poker usage per week	2	2.0	7.0	4.500	3.5355
Snow Bros per week	1	1.0	1.0	1.000	.
Super Mario Brothers per week	1	1.0	1.0	1.000	.
Jetpack Joyride usage per week	1	.0	.0	.000	.
Subway Surfer usage per week	1	5.0	5.0	5.000	.
Threes usage per week	1	5.0	5.0	5.000	.
ChessPro usage per week	1	3.0	3.0	3.000	.
Minion Rush usage per week	1	2.5	2.5	2.500	.
Arcade Shooter usage per week	1	3.0	3.0	3.000	.
Clash of Clans usage per week	2	2.0	10.0	6.000	5.6569
HobbitKom usage per	1	2.0	2.0	2.000	.
Flappy Bird usage per	1	1.0	1.0	1.000	.
Minecraft usage per week	1	4.0	4.0	4.000	.
Valid N (listwise)	0				

Appendix O. Game performance

O1. Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Win/Loss pre-training	17	2.00	.000	2	2
Unit score pre-training	17	4923.53	11371.832	400	48625
Structure score pre-training	17	1899.88	3392.191	400	14765
Resources score pre-training	17	5675.29	10779.757	1106	46888
Total score pre-training	17	12467.88	25507.937	2146	110278
Game time in minutes pre-training	17	12.59	4.244	8	25
Win/Loss Post-training	17	1.18	.393	1	2
Unit score post-training	17	101887.65	141614.249	2580	511600
Structure score post-training	17	19083.24	19174.442	1140	60440
Resources score post-training	17	31003.18	29807.811	1114	94095
Total score post-training	17	151984.71	185704.728	7466	666136
Game time in minutes post-training	17	43.12	31.365	9	100

O2. Wilcoxon Signed Ranks Tests

Test Statistics[c]

	Win/Loss Post-training - Win/Loss pre-training	Unit score post-training - Unit score pre-training	Structure score post-training - Structure score pre-training	Resources score post-training - Resources score pre-training	Total score post-training - Total score pre-training	Game time in minutes post-training - Game time in minutes pre-training
Z	-3.742[a]	-3.243[b]	-3.243[b]	-3.290[b]	-3.290[b]	-3.310[b]
Asymp. Sig. (2-tailed)	.000	.001	.001	.001	.001	.001

a. Based on positive ranks.

b. Based on negative ranks.

c. Wilcoxon Signed Ranks Test

Appendix P. Self-reported Coloured subjects vs. sample averages

P1: Descriptive statistics - proportional switch costs of subject X, Y and sample

Category	Proportional SwitchCost1	Proportional SwitchCost2	Neterrors1	NetErrors2
Subject X (control)	6.53	8.34	0.10	0.11
Subject Y (experimental)	1.77	4.04	0.07	0.04
Control Average	15.559	13.557	0.109	0.118
Experiment Average	16.144	11.270	0.092	0.088
Whole Sample Average	15.851	12.413	0.101	0.103

P2: Descriptive statistics – Video gaming expertise for subject X, Y and sample

Category	Subject X (control)	Subject Y (experimental)	Control Average	Experiment Average	Whole Sample Average
RPG Expertise	6.00	7.00	3.18	4.35	3.77
Fighting Expertise	6.00	6.00	4.53	3.77	4.15
Sports Expertise	7.00	7.00	4.18	3.12	3.65
Average Expertise	3.90	4.50	3.18	3.13	3.15

P3: Descriptive statistics – Video game usage per week for subject X, Y and sample

Category	Subject X (control)	Subject Y (experimental)	Control Average	Experiment Average	Whole Sample Average
RPG hours per week	4.00	10.00	1.88	2.82	2.35
Fighting hours per week	3.00	4.00	2.21	1.18	1.69
Sports hours per week	5.00	8.00	2.71	1.68	2.19
Average hours per week	2.30	3.90	1.64	1.74	1.69

Appendix Q. Female proportional switch costs

Q1: Summary of statistical tests

	Proportional Switch Cost 1	Proportional Switch Cost 2	Test Used	p-value	Significance
Whole Group	[a] 15.009	[b] 8.829	Non-Parametric Wilcoxon Signed Ranks Test *(a - b)*	0.249	Not Significant
Control Group	[c] 12.076	[d] 12.176	Non-Parametric Wilcoxon Signed Ranks Test *(c - d)*	N/A	N/A
Experimental Group	[e] 17.942	[f] 5.482	Non-Parametric Wilcoxon Signed Ranks Test *(e - f)*	0.109	Not Significant
Test Used	Non-Parametric Mann-Whitney Test *(c-e)*	Non-Parametric Mann-Whitney Test *(d-f)*			
p-value	0.513	0.275			
Significance	Not Significant	Not Significant			

Q2: Descriptive statistics

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
ProportionalSwitchCost1	6	15.00924793898600	9.073753298455300	5.662459301170	28.643434418624
ProportionalSwitchCost2	6	8.82861934161512	7.764697810729750	3.437709778586	23.926811982068
Group	6	1.50	.548	1	2

Q3: Proportional switch cost pre and post-training: female control vs. female experimental

Mann-Whitney Test

Ranks

Group		N	Mean Rank	Sum of Ranks
ProportionalSwitchCost1	Control	3	3.00	9.00
	Experimental	3	4.00	12.00
	Total	6		
ProportionalSwitchCost2	Control	3	4.33	13.00
	Experimental	3	2.67	8.00
	Total	6		

Test Statistics[a]

	ProportionalSwitchCost1	ProportionalSwitchCost2
Mann-Whitney U	3.000	2.000
Wilcoxon W	9.000	8.000
Z	-.655	-1.091
Asymp. Sig. (2-tailed)	.513	.275
Exact Sig. [2*(1-tailed Sig.)]	.700[b]	.400[b]

a. Grouping Variable: Group

b. Not corrected for ties.

Q4: Proportional switch cost pre-training vs. proportional switch cost post-training: whole female sample

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
ProportionalSwitch Cost1	6	15.0092479389 8600	9.07375329845 5300	5.662459301 170	28.643434418 624
ProportionalSwitch Cost2	6	8.82861934161 512	7.76469781072 9750	3.437709778 586	23.926811982 068

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
ProportionalSwitchCost2 - ProportionalSwitchCost1	Negative Ranks	4[d]	4.00	16.00
	Positive Ranks	2[e]	2.50	5.00
	Ties	0[f]		
	Total	6		

d. ProportionalSwitchCost2 < ProportionalSwitchCost1

e. ProportionalSwitchCost2 > ProportionalSwitchCost1

f. ProportionalSwitchCost2 = ProportionalSwitchCost1

Test Statistics[a]

	ProportionalSwitchCost2 - ProportionalSwitchCost1
Z	-1.153[b]
Asymp. Sig. (2-tailed)	.249

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

Q5: Proportional switch cost pre-training vs. proportional switch cost post-training: control group

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
ProportionalSwitchCost1	3	12.07603013227930	8.073534391136610	5.662459301170	21.142127748137
ProportionalSwitchCost2	3	12.17552915784790	10.536632440229000	3.570210627583	23.926811982068

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
ProportionalSwitchCost2 - ProportionalSwitchCost1	Negative Ranks	1[d]	3.00	3.00
	Positive Ranks	2[e]	1.50	3.00
	Ties	0[f]		
	Total	3		

d. ProportionalSwitchCost2 < ProportionalSwitchCost1

e. ProportionalSwitchCost2 > ProportionalSwitchCost1

f. ProportionalSwitchCost2 = ProportionalSwitchCost1

Test Statistics[a]

	ProportionalSwitchCost 2 - ProportionalSwitchCost 1
Z	.000[b]
Asymp. Sig. (2-tailed)	1.000

a. Wilcoxon Signed Ranks Test

b. The sum of negative ranks equals the sum of positive ranks.

c. Based on negative ranks.

d. Based on positive ranks.

Q6: Proportional switch cost pre-training vs. proportional switch cost post-training: experimental group

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
ProportionalSwitch Cost1	3	17.9424657456 9260	10.71630718267 5500	7.210885635 207	28.643434418 624
ProportionalSwitch Cost2	3	5.48170952538 236	2.469876736885 370	3.437709778 586	8.2261611025 24

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
ProportionalSwitch Cost2 - ProportionalSwitch Cost1	Negative Ranks	3[d]	2.00	6.00
	Positive Ranks	0[e]	0.00	0.00
	Ties	0[f]		
	Total	3		

d. ProportionalSwitchCost2 < ProportionalSwitchCost1

e. ProportionalSwitchCost2 > ProportionalSwitchCost1

f. ProportionalSwitchCost2 = ProportionalSwitchCost1

Test Statistics[a]

	ProportionalSwitch Cost2 - ProportionalSwitch Cost1
Z	-1.604[b]
Asymp. Sig. (2-tailed)	.109

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. The sum of negative ranks equals the sum of positive ranks.

d. Based on negative ranks.

Appendix R. Proportional switch costs – males vs. females

R1: Summary of statistical tests

	Proportional Switch Cost 1	Proportional Switch Cost 2
Experimental Male	[c] **15.759**	[d] **12.510**
	↕	↕
Experimental Female	[e] **17.942**	[f] **5.482**
Test Used	**Non-Parametric Mann-Whitney Test** ***(c-e)***	**Non-Parametric Mann-Whitney Test** ***(d-f)***
p-value	**0.801**	**0.313**
Significance	**Not Significant**	**Not Significant**

R2: Proportional switch cost pre-training and post-training: male vs. female

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum
ProportionalSwitchCost1	17	16.14395912855350	12.178789176520300	-3.435473852648
ProportionalSwitchCost2	17	11.26960140407560	9.313679223365930	-1.944789605760
Gender	17	1.18	.393	1

Mann-Whitney Test

Ranks

Gender		N	Mean Rank	Sum of Ranks
ProportionalSwitchCost1	1	14	8.86	124.00
	2	3	9.67	29.00
	Total	17		
ProportionalSwitchCost2	1	14	9.57	134.00
	2	3	6.33	19.00
	Total	17		

Test Statistics[a]

	ProportionalSwitchCost1	ProportionalSwitchCost2
Mann-Whitney U	19.000	13.000
Wilcoxon W	124.000	19.000
Z	-.252	-1.008
Asymp. Sig. (2-tailed)	.801	.313
Exact Sig. [2*(1-tailed Sig.)]	.859[b]	.362[b]

Appendix S. Task switching behaviours

S1: Working/studying alone

	N	Mean	Std. Deviation
Listen to music/radio whilst studying/working alone	34	2.65	1.807
Eat/drink whilst studying/working alone	34	2.82	1.029
Check email on PC/mobile device intermittently whilst studying/working alone	34	2.91	1.422
Use Facebook/Twitter/Social networking sites on mobile device/PC whilst studying/working alone	34	3.00	1.706
Instant Messaging whilst studying/working alone	34	4.15	1.579
Play video games on PC/mobile device whilst studying/working alone	34	2.59	1.459

Test Statistics

	Listen to music/radio whilst studying/working alone	Eat/drink whilst studying/working alone	Check email on PC/mobile device intermittently whilst studying/working alone	Use Facebook/Twitter/Social networking sites on mobile device/PC whilst studying/working alone	Instant Messaging whilst studying/working alone	Play video games on PC/mobile device whilst studying/working alone
Chi-Square	24.588[a]	29.529[a]	11.176[a]	12.588[a]	8.706[a]	15.765[a]
df	5	5	5	5	5	5
Asymp. Sig.	.000	.000	.048	.028	.121	.008

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 5.7.

Listen to music/radio whilst studying/working alone

	Observed N	Expected N	Residual
Not at all	10	5.7	4.3
1-20% of the time	14	5.7	8.3
21-40% of the time	1	5.7	-4.7
41-60% of the time	1	5.7	-4.7
61-80% of the time	3	5.7	-2.7
>80% of the time	5	5.7	-.7
Total	34		

Frequencies

	Eat/drink whilst studying/working alone			
	Category	**Observed N**	**Expected N**	**Residual**
1	Not at all	1	5.7	-4.7
2	1-20% of the time	15	5.7	9.3
3	21-40% of the time	10	5.7	4.3
4	41-60% of the time	5	5.7	-.7
5	61-80% of the time	3	5.7	-2.7
6		0	5.7	-5.7
Total		34		

Check email on PC/mobile device intermittently whilst studying/working alone

	Observed N	**Expected N**	**Residual**
Not at all	5	5.7	-.7
1-20% of the time	12	5.7	6.3
21-40% of the time	5	5.7	-.7
41-60% of the time	6	5.7	.3
61-80% of the time	5	5.7	-.7
>80% of the time	1	5.7	-4.7
Total	34		

Use Facebook/Twitter/Social networking sites on mobile device/PC whilst studying/working alone

	Observed N	**Expected N**	**Residual**
Not at all	6	5.7	.3
1-20% of the time	13	5.7	7.3
21-40% of the time	3	5.7	-2.7
41-60% of the time	3	5.7	-2.7
61-80% of the time	5	5.7	-.7
>80% of the time	4	5.7	-1.7
Total	34		

Instant Messaging whilst studying/working alone

	Observed N	**Expected N**	**Residual**
Not at all	1	5.7	-4.7
1-20% of the time	5	5.7	-.7
21-40% of the time	8	5.7	2.3
41-60% of the time	4	5.7	-1.7
61-80% of the time	6	5.7	.3
>80% of the time	10	5.7	4.3
Total	34		

Play video games on PC/mobile device whilst studying/working alone

	Observed N	**Expected N**	**Residual**
Not at all	8	5.7	2.3
1-20% of the time	13	5.7	7.3
21-40% of the time	4	5.7	-1.7
41-60% of the time	5	5.7	-.7
61-80% of the time	2	5.7	-3.7
>80% of the time	2	5.7	-3.7

Frequencies

	Eat/drink whilst studying/working alone			
	Category	**Observed N**	**Expected N**	**Residual**
1	Not at all	1	5.7	-4.7
2	1-20% of the time	15	5.7	9.3
3	21-40% of the time	10	5.7	4.3
4	41-60% of the time	5	5.7	-.7
5	61-80% of the time	3	5.7	-2.7
6		0	5.7	-5.7
Total		34		

S2: Other actions reported

Switching between work tasks whilst studying/working alone - falls under "other"

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	21-40% of the time	1	2.9	100.0	100.0
Missing	System	34	97.1		
Total		35	100.0		

Read comics whilst studying/working alone - falls under "other"

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	>80% of the time	1	2.9	100.0	100.0
Missing	System	34	97.1		
Total		35	100.0		

Talk over the phone whilst studying/working alone - falls under "other"

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-20% of the time	1	2.9	100.0	100.0
Missing	System	34	97.1		
Total		35	100.0		

Watch TV whilst studying/working alone - falls under "other"

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-20% of the time	1	2.9	33.3	33.3
	41-60% of the time	1	2.9	33.3	66.7
	>80% of the time	1	2.9	33.3	100.0
	Total	3	8.6	100.0	
Missing	System	32	91.4		
Total		35	100.0		

S3: Working/studying in a group

	N	Mean	Std. Deviation
Listen to music/radio whilst studying/working in a group	34	1.47	.929
Eat/drink whilst studying/working group	34	2.62	1.101
Check email on PC/mobile device intermittently whilst studying/working in a group	34	2.15	1.351
Use Facebook/Twitter/Social networking sites on mobile device/PC whilst studying/working in a group	34	2.15	1.520
Instant Messaging whilst studying/working in a group	34	3.03	1.487
Play video games on PC/mobile device whilst studying/working in a group	34	1.65	1.178

Test Statistics

	Listen to music/radio whilst studying/working in a group	Eat/drink whilst studying/working group	Check email on PC/mobile device intermittently whilst studying/working in a group	Use Facebook/Twitter/Social networking sites on mobile device/PC whilst studying/working in a group	Instant Messaging whilst studying/working in a group	Play video games on PC/mobile device whilst studying/working in a group
Chi-Square	82.471[a]	24.235[a]	24.235[a]	34.824[a]	6.235[a]	64.471[a]
df	5	5	5	5	5	5
Asymp. Sig.	.000	.000	.000	.000	.284	.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 5.7.

Listen to music/radio whilst studying/working in a group

	Observed N	Expected N	Residual
Not at all	25	8.5	16.5
1-20% of the time	5	8.5	-3.5
21-40% of the time	1	8.5	-7.5
41-60% of the time	3	8.5	-5.5
Total	34		

Eat/drink whilst studying/working group

	Observed N	Expected N	Residual
Not at all	4	6.8	-2.8
1-20% of the time	15	6.8	8.2
21-40% of the time	7	6.8	.2
41-60% of the time	6	6.8	-.8
61-80% of the time	2	6.8	-4.8
Total	34		

Check email on PC/mobile device intermittently whilst studying/working in a group

	Observed N	**Expected N**	**Residual**
Not at all	14	5.7	8.3
1-20% of the time	10	5.7	4.3
21-40% of the time	5	5.7	-.7
41-60% of the time	2	5.7	-3.7
61-80% of the time	2	5.7	-3.7
>80% of the time	1	5.7	-4.7
Total	34		

Use Facebook/Twitter/Social networking sites on mobile device/PC whilst studying/working in a group

	Observed N	Expected N	Residual
Not at all	18	5.7	12.3
1-20% of the time	4	5.7	-1.7
21-40% of the time	6	5.7	.3
41-60% of the time	3	5.7	-2.7
61-80% of the time	1	5.7	-4.7
>80% of the time	2	5.7	-3.7
Total	34		

Instant Messaging whilst studying/working in a group

	Observed N	Expected N	Residual
Not at all	5	5.7	-.7
1-20% of the time	10	5.7	4.3
21-40% of the time	7	5.7	1.3
41-60% of the time	5	5.7	-.7
61-80% of the time	5	5.7	-.7
>80% of the time	2	5.7	-3.7
Total	34		

Play video games on PC/mobile device whilst studying/working in a group

	Observed N	Expected N	Residual
Not at all	22	8.5	13.5
1-20% of the time	8	8.5	-.5
21-40% of the time	1	8.5	-7.5
61-80% of the time	3	8.5	-5.5
Total	34		

Test Statistics[b]

	Listen to music/radio whilst studying/working in a group - Listen to music/radio whilst studying/working alone	Eat/drink whilst studying/working group - Eat/drink whilst studying/working alone	Check email on PC/mobile device intermittently whilst studying/working in a group - Check email on PC/mobile device intermittently whilst studying/working alone	Use Facebook/Twitter/Social networking sites on mobile device/PC whilst studying/working in a group - Use Facebook/Twitter/Social networking sites on mobile device/PC whilst studying/working alone	Instant Messaging whilst studying/working in a group - Instant Messaging whilst studying/working alone	Play video games on PC/mobile device whilst studying/working in a group - Play video games on PC/mobile device whilst studying/working alone
Z	-3.694[a]	-1.063[a]	-3.244[a]	-3.520[a]	-4.193[a]	-3.739[a]
Asymp. Sig. (2-tailed)	.000	.288	.001	.000	.000	.000

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

S4: While driving

	N	Mean	Std. Deviation
Listen to music/radio whilst studying/working whilst driving	32	5.13	1.100
Switch radio stations/change CDs whilst driving	32	3.50	1.934
Eat/drink whilst driving	32	2.56	1.343
Check email on mobile device intermittently whilst driving	32	1.38	.976
Text via Instant Messaging whilst driving	32	2.72	1.708
Talk to a passenger	32	4.25	1.459
Talk over your mobile device	32	2.41	1.500
Use Facebook/Twitter/Social networking sites on mobile device whilst driving	32	1.44	1.268
Play video games or other games on mobile device whilst driving	32	1.09	.530
Put make-up/groom yourself whilst driving	32	1.28	.958

Test Statistics

	Listen to music/radio whilst studying/working whilst driving	Switch radio stations/change CDs whilst driving	Eat/drink whilst driving	mobile device intermittently whilst driving	Text via Instant Messaging whilst driving	Talk to a passenger	Talk over your mobile device	Use Facebook/Twitter/Social networking sites on mobile device whilst driving	Play video games or other games on mobile device whilst driving	Put make-up/groom yourself whilst driving
Chi-Square	39.250[a]	5.500[a]	27.625[a]	90.250[a]	11.500[a]	7.750[a]	14.875[a]	106.375[a]	148.375[a]	116.125[a]
df	5	5	5	5	5	5	5	5	5	5
Asymp. Sig.	.000	.358	.000	.000	.042	.171	.011	.000	.000	.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 5.3.

Listen to music/radio whilst studying/working whilst driving

	Observed N	Expected N	Residual
1-20% of the time	1	6.4	-5.4
21-40% of the time	1	6.4	-5.4
41-60% of the time	8	6.4	1.6
61-80% of the time	5	6.4	-1.4
>80% of the time	17	6.4	10.6
Total	32		

Switch radio stations/change CDs whilst driving

	Observed N	Expected N	Residual
Not at all	6	5.3	.7
1-20% of the time	8	5.3	2.7
21-40% of the time	2	5.3	-3.3
41-60% of the time	4	5.3	-1.3
61-80% of the time	4	5.3	-1.3
>80% of the time	8	5.3	2.7
Total	32		

Eat/drink whilst driving

	Observed N	Expected N	Residual
Not at all	5	5.3	-.3
1-20% of the time	16	5.3	10.7
21-40% of the time	4	5.3	-1.3
41-60% of the time	4	5.3	-1.3
61-80% of the time	1	5.3	-4.3
>80% of the time	2	5.3	-3.3
Total	32		

Check email on mobile device intermittently whilst driving

	Observed N	Expected N	Residual
Not at all	25	8.0	17.0
1-20% of the time	5	8.0	-3.0
21-40% of the time	1	8.0	-7.0
>80% of the time	1	8.0	-7.0
Total	32		

Frequencies

	Text via Instant Messaging whilst driving			
	Category	**Observed N**	**Expected N**	**Residual**
1	Not at all	9	5.3	3.7
2	1-20% of the time	9	5.3	3.7
3	21-40% of the time	6	5.3	.7
4	41-60% of the time	3	5.3	-2.3
5	61-80% of the time	0	5.3	-5.3
6	>80% of the time	5	5.3	-.3
Total		32		

Talk to a passenger

	Observed N	**Expected N**	**Residual**
Not at all	2	5.3	-3.3
1-20% of the time	2	5.3	-3.3
21-40% of the time	5	5.3	-.3
41-60% of the time	7	5.3	1.7
61-80% of the time	9	5.3	3.7
>80% of the time	7	5.3	1.7
Total	32		

Talk over your mobile device

	Observed N	**Expected N**	**Residual**
Not at all	11	5.3	5.7
1-20% of the time	9	5.3	3.7
21-40% of the time	6	5.3	.7
41-60% of the time	2	5.3	-3.3
61-80% of the time	2	5.3	-3.3
>80% of the time	2	5.3	-3.3
Total	32		

Use Facebook/Twitter/Social networking sites on mobile device whilst driving

	Observed N	**Expected N**	**Residual**
Not at all	**27**	**8.0**	**19.0**
1-20% of the time	2	8.0	-6.0
21-40% of the time	1	8.0	-7.0
>80% of the time	2	8.0	-6.0
Total	32		

Play video games or other games on mobile device whilst driving

	Observed N	Expected N	Residual
Not at all	**31**	**16.0**	**15.0**
41-60% of the time	1	16.0	-15.0
Total	32		

Put make-up/groom yourself whilst driving

	Observed N	Expected N	Residual
Not at all	**28**	**8.0**	**20.0**
1-20% of the time	2	8.0	-6.0
21-40% of the time	1	8.0	-7.0
>80% of the time	1	8.0	-7.0
Total	32		

Appendix T. Gatekeeper's letter

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

13 June 2013

Mr Y Ismail
School of Management, IT and Governance
Westville Campus
UKZN

Email: 207511342@stu.ukzn.ac.za / yismail786@gmail.com

Dear Mr Ismail,

RE: PERMISSION TO CONDUCT RESEARCH

Gatekeeper's permission is hereby granted for you to conduct research at the University of KwaZulu-Natal towards your postgraduate studies, provided Ethical clearance has been obtained. We note the title of your research project is:

"Real-Time Stategy Games and Task Switching"

It is noted that you will be constituting your sample by randomly handing out questionnaires to students on the Westville Campus.

Data collected must be treated with due confidentiality and anonymity.

Yours sincerely

Professor J J Meyerowitz
REGISTRAR

Office of the Registrar
Postal Address: Private Bag X54001, Durban, South Africa
Telephone: +27 (0) 31 260 8005/2206 Facsimile: +27 (0) 31 260 7824/2204 Email: registrar@ukzn.ac.za
Website: www.ukzn.ac.za

1910 - 2010
100 YEARS OF ACADEMIC EXCELLENCE

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

Appendix U. Ethical clearance

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

E ✓
O ✓
CS ✓
DD ✓

17 July 2013

Mr Yusuf Ismail 207511342
School of Management, IT and Governance
Westville Campus

Protocol reference number: HSS/0398/013M
Project title: "Real-Time Strategy Games and Task Switching"

Dear Mr Ismail

Full Approval – Expedited

This letter serves to notify you that your application in connection with the above has now been granted full approval.

Any alterations to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach/Methods must be reviewed and approved through an amendment /modification prior to its implementation. Please quote the above reference number for all queries relating to this study. PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years.

Best wishes for the successful completion of your research protocol

Yours faithfully

Professor U Bob (Chair) & Dr S Singh (Deputy Chair)

/px

cc Supervisor: Mr C Blewett
cc Academic Leader Research: Professor B McArthur
cc School Administrator: Ms Hazvinei Muteswa

Humanities & Social Sciences Research Ethics Committee
Professor Urmila Bob (Chair) and Dr Shenuka Singh (Deputy Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban, 4000, South Africa
Telephone: +27 (0)31 260 3587/8350/4557 **Facsimile:** +27 (0)31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
Website: www.ukzn.ac.za

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

INSPIRING GREATNESS