VIDEO GAME PLAYING: ITS EFFECTS ON DIVIDED ATTENTION, ENCODING AND RETRIEVAL PROCESSES OF HUMAN MEMORY

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STUDENT DECLARATION

"I, Lata Satyen, declare that the Ph.D thesis entitled Video Game Playing: Its Effects on Divided Attention, Encoding and Retrieval Processes of Human Memory, is no more than 100,00 words in length, exclusive of tables, figures, appendices, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work."

Signature: [redacted]

Date: 14/12/05

DEDICATION

This thesis is dedicated to my parents, Mr. V. Satyen and Mrs. Rukmini Satyen, and to my husband, Aiman.

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ABSTRACT

Skills of divided attention are important to perform a multitude of tasks. However, there is a dearth of previous research that has investigated means to improve these skills. The present study investigated the use of video games as a training tool to enhance skills of divided attention, explored the influence of video game training on the encoding and retrieval processes of human memory, and thirdly, examined the differential influence of video game training and the process of divided attention on the encoding and retrieval processes of memory. It was hypothesised that video game training: (a) would enhance divided attention skills, (b) would influence encoding and retrieval processes by reducing costs associated with their performance in a dual-attention condition, and, (c) along with the process of divided attention, differentially affect encoding and retrieval processes. Fifty participants took part in Study 1 and 2 that examined the influence of short-term and long-term training with video games on cognitive skills, respectively. Only participants in the Training group were provided with a one-hour or six-hour training with a video game. Performance on memory and Reaction Time tasks was assessed before and after training in a series of experiments. Results showed that training with video games leads to: (a) an improvement in the skills of divided attention, (b) reduction in costs associated with memory performance in a dual-attention condition. The findings have important implications for the use of video games as training tools to improve skills of divided attention to increase efficiency on a range of tasks including flight performance, air traffic control, operation of heavy equipment, and motor driving.

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INTRODUCTION

Video games are a ubiquitous interactive entertainment medium. Although past research has investigated the effects of video game playing on social skills and eye-hand co-ordination skills, there is a dearth of research into the effects of video game playing on important cognitive skills such as divided attention. A few previous studies have explored the capability of video games to provide strategies to improve divided visual attention skills (Green & Bavelier, 2003; Greenfield, DeWinstanley, Kilpatrcik, & Kaye, 1994). However, the capacity of video games to improve skills of divided attention has not been researched thoroughly.

Considering that skills of divided attention are necessary to perform a range of tasks including air traffic control, flight performance, operation of heavy equipment, motor driving, playing a piano, performing secretarial duties and in class, students taking notes while listening to the lecturer, it is important to investigate how these skills could be improved. However, there are only a handful of studies (e.g., Hirst, Spelke, Reaves, Caharack, & Neisser, 1980) that have investigated means of improving these skills. Therefore, the first objective of the present study was to investigate whether video game training could improve skills of divided attention.

The process of divided attention affects encoding and retrieval processes of human memory. Research has found that division of attention leads to a deficit in memory performance and the concurrent secondary task performance (Craik, Govoni, Naveh-Benjamin, & N.D. Anderson, 1996). However, to date, there is no research that has investigated means of reducing this deficit in performance. It is argued that if video game training has the capacity to improve divided attention skills (after Greenfield, DeWinstanley et al., 1996), then it could have the potential to alter the effects of divided attention on encoding and retrieval by reducing the costs associated primary and secondary task performance. Therefore, the aim of present study was to examine whether training with video games could lead to reduction in costs associated with memory and concurrent secondary task performance in a dual-attention condition.

Previous research has also found that the process of divided attention affects encoding and retrieval processes differentially (Craik et al., 1996). This pattern of influence is such that division of attention at encoding is more disruptive to recall performance than is divided attention at retrieval. On the other hand, concurrent secondary task performance is affected to a larger extent by divided attention at retrieval than by divided attention at encoding. It is not clear whether this differential effect of divided attention on memory processes could be altered. Therefore, the objective of the present study was to explore whether training with video games could alter the differential effect of divided attention on the encoding and retrieval processes of memory.

LITERATURE REVIEW

This chapter presents a review of the literature relating to the effects of video games, the cognitive process of divided attention, the memory processes of encoding and retrieval, and the interaction between divided attention and memory processes. The theoretical underpinnings of the thesis arise from the applied cognitive theory related to the influence of video game playing on the cognitive process of divided attention and from the cognitive theories of attention and memory. The first part reviews the effects of video game playing on the social, developmental and cognitive processes. The second section provides an introduction to 'Attention,' covers some of the relevant theories of attention and elaborates on the process of divided attention. The third section in this chapter reviews the literature in relation to memory, describing some of the prominent theories and then elaborating on the processes of encoding and retrieval. The final section examines the interaction between divided attention and the memory processes of encoding and retrieval. The rationale for the current investigation is then provided along with the objectives and statement of hypotheses of the current study. The glossary presented after the 'References' section provides a list of definitions of key terms used in the study.

VIDEO GAMES AND THEIR INFLUENCE

Introduction to Video Games

Video games have become immensely popular over the past three decades. Irrespective of whether one approves of them or not, they are here to stay. As Durkin and Aisbett (1999) point out, the games "are set to become almost as ubiquitous as television is today" (p. 30). The majority of games are entertaining, engrossing, and interactive, and satisfy a thirst for thrill and excitement - more so amongst the younger generation. With each passing year, the video game industry is booming and the statistics display constant surges in sales. Competitive publishers of video games are releasing newer and more powerful video game systems every year and sales gross more than US$15 billion annually in the U.S. alone, and over AU$750 million in Australia (Durkin & Aisbett, 1999; Gfk Australia, 2004).

The latest Australian statistics for the sale of video game hardware and software equipment reveals that the popularity of video games is steadily increasing.

Table 1

Sales figures of video and computer games in Australia, 2000 – 2004.

Device	2000	2001	2002	2003	2004 (to 30th November)
Software	$241,461,799	$281,094,343	$361,354,917	$432,658,775	$442,420,042
Hardware	$151,588,727	$241,996,764	$374,955,864	$318,316,719	$210,420,439
Total	$393,050,526	$523,091,107	$736,310,782	$750,975,494	$652,840,481

From: "Sales figures of video and computer game sales," by Gfk Australia, (personal communication, December, 2004).

Table 1 shows the continual increase in video game software and hardware sales over the past five years. The figures included are from 90-95 % of retailers who are members of the Australian Visual Software Distributors Association. Further, the video game market penetration of more than 6.7 million Australian homes (Durkin & Aisbett, 1999), and many more millions of homes worldwide, warrants the investigation of the effects the games on its users.

Debates Surrounding Video Games

Many researchers have ascertained the importance of video games in young peoples' lives. In evaluating the impact of the games, Funk (1993) argues "this pastime has a solid role in the lives of young adolescents and perhaps a corresponding influence which should not be dismissed" (p. 89).

The popularity of the electronic games has led to a plethora of debates concerning the impact they have on users. The most prominent debates seem to be on the negative effects such as increasing aggression or violent behaviour, most of which are not well warranted. However, there are many positive gains that could be achieved by introducing these games into society, which cannot be overlooked. Although some research has been conducted to explore the influence of these games, there have been inconsistent findings.

Some studies have clearly established a link between game play and skill development (Porter, 1995) including response time (Clark, Lanphear, & Riddick, 1987; Dustman, Emmerson, Steinhaus, Shearer, & Dustman, 1992), spatial skills (Okagaki & Frensch, 1994; Subrahmanyam & Greenfield, 1994), enhancing social behaviour, such as bringing families together in common recreational interaction, encouraging co-ooperation (Mitchell, 1985), a release of aggressive tendencies thereby aiding young adults in the developmental process (Gardner, 1993; Provenzo, 1991), enhancing self-esteem as the player gains mastery (Nelson & Carlson, 1985; Turkle, 1984) and providing a means of relaxation and enjoyment (Greenfield, 1984). As video games are being increasingly used in therapeutic and medical settings, the important role they play in providing positive health and therapeutic potential have also been realised (Griffiths, 2004).

Others have criticized the games for their negative influence, such as the prominent suggestion that video game playing leads to aggressive tendencies (C.A. Anderson & Dill, 2000; Colwell & Payne, 2000), or delaying the development of social skills (Egli & Meyers, 1984), which have not fully been substantiated. For example, Colwell and Payne (2000) found a correlation between aggression scores and total exposure to game play only, but not between aggression scores and the number of games with aggressive content. C.A. Anderson and Dill (2000) also found only a minor correlation between game play and violent behaviour. After an extended study, Cooper and Mackie (1986) concluded that there was no evidence to suggest that playing aggressive games could lead to aggressive behaviour. They argued that if the games induced aggressive behaviour, that behaviour would be strongest immediately after playing. However, no such actions were observed.

Some of the other negative effects that have been described have also not been validated by other studies. For example, Gibb, Bailey, Lornbirth, and Wilson (1983) investigated the relationship between the amount of time spent playing video games and important personality dimensions of self-esteem/ self-degradation, social deviance/ social conformity, hostility/ kindness, social withdrawal/ gregariousness, and obsessiveness and compulsiveness. Their findings did not reveal a significant relationship between video game playing and the different measures. Similarly, after surveying a large number of video game players, Brooks (1983) concluded that video game playing was not as "addictive" or "compulsive" as it may appear. What he discovered was that youth spent less than half their time in arcades actually playing games; the rest of the time was spent talking and engaging in social interactions. Another study (Colwell, Grady, & Rhaiti, 1995) also concluded that there was no support for the theory that computer games were taking the place of normal social interaction, as it found that "heavy" players were in fact more likely to meet their friends outside school hours than the infrequent players.

After an extensive study among the Australian population, Durkin and Aisbett (1999) suggest that there is no evidence that members of the community perceive the games as a major social problem and affirm that the independent research that has been published until now does not yield any serious effects of aggressive game play on young people's behaviour. In a more recent study investigating the relationship between game play and several measures of adjustment or risk taking in over 1,000 high school students, Durkin and Barber (2002) found no evidence of negative outcomes among game players. On the contrary, they suggested that computer games could be a positive feature of a healthy adolescence.

There are therefore two major groups of individuals – one asserting the positive gains by playing the video game and the other deploring the negative influence of the games. Thus, contradicting findings of the effects of video games further emphasise the need to clarify the ambivalent status of this medium of technology.

Attractiveness of the Games

The history of video games dates back to 1966 when Ralph Baer first construed the idea for a simple two-player video game. But the initial wave of interest in video games started when 'Atari' introduced 'Pong,' an electronic table-tennis game in 1972. The game rapidly spread and become very popular, after which several different games and platforms to play the games were introduced. Although initially the games were mainly played in the arcade, the home market boomed with the advent of the personal video game system in 1972 (Provenzo, 1991).

Since the games foster interest among a wide range of people, it becomes necessary to examine some key questions: Why are video games so popular? What is it that drives people to play them? And what is it about the games that make people play them again and again? In attempting to answer some of these questions, Malone (1981) and Lepper (1985) suggested that intrinsic motivation produces positive internal rewards thereby driving people to play the games. Malone (1981) proposed that intrinsic motivation is a function of three primary factors: challenge, curiosity, and fantasy, all of which, he suggested, should be incorporated into a game to make it more enjoyable. Similarly, Kaplan and Kaplan (1981) declared "video games themselves are so inherently and intrinsically compelling that no additional seduction, sexual or otherwise, would be necessary to attract players" (p. 208), when questions were raised as to whether or not a video game without sexual references would be attractive.

A very attractive feature of the video game is that it is interactive because of which the player can control the situation and his or her actions rather than being a passive participant. Thus Durkin and Aisbett (1999) aptly remarked, "fundamental to the attraction of video and computer games was the sense, for the young player, of power and being in control which was uncommon in their normal lives" (p. 69). They also assert that the games are popular because the degree of autonomy and control they offer is not achievable in other forms of media such as television and film.

With regard to the aim for playing the games, Malone (1981) found that the presence of a goal was the most important determinant for the popularity of the games. Some of the other qualities that enhanced the attractiveness of the game were the audio effects, randomness in the occurrence of events, the emphasis on speed of response, visual effects, and competition (Malone, 1981). The dynamic and robust qualities of the game are some of the other attractive features that capture the attention of players who become immersed (Greenfield, 1993) and interact with the fantasy worlds of the games (Sigel & Cocking, 1977), which therefore make them appealing to both children and adults. In addition, Johnson (1993) differentiates video games from traditional toys in that the former can be manipulated and moved and generates a wide variety of responses compared to the latter which generates only limited numbers of responses.

Selnow (1984) suggests that video game playing is complementary to television viewing and hence provides a means of gratification of personal needs for passing time, relaxation, companionship, and a sense of personal involvement in the action. Durkin and Aisbett (1999) also contend that the main motives for game play among young people and adults, are enjoyment, diversion, and challenge. Furthermore, they indicate that these are psychologically healthy motives that are common to many leisure activities and hence the concern regarding playing the games is unwarranted.

According to Malone (1981) and Nawrocki and Winner (1983), the most effective incentive in playing video games is the presence of the highest game score, which acts as a strong motivator to play repeatedly to either increase the player's scoring ability or to better other players' scores. High scores can be achieved as a result of individual skill, which is the ultimate judge of competence in a video game arena; thus a small child can compete against an older and stronger adversary (Turkle, 1984) and still exhibit his or her supremacy through better game play.

Greenfield (1984) identified some of the other features that make the game popular in her seminal book 'Mind and Media.' She indicates that the games are appealing because of the tremendous amount of visual action, which has also been considered an important element in also attracting people to the television screen. Similarly, Malone (1981) found that visual elements were important in the games' popularity. For this reason, video games have been described as the "first medium to combine visual dynamism with an active participatory role" (Greenfield, 1984, p. 90).

The video game has tremendous social importance because of its nature as a mass medium; hence, Greenfield (1994) has aptly described it as a "cultural artifact." McLuhan (1964, 2001) has elaborated on the importance of games in general in society in his book, 'Understanding Media: The Extensions of Man.'

> Games are popular art, collective, social reactions to the main drive or action of any culture. Games, like institutions, are extensions of social man and of the body politic, as technologies are extensions of the animal organism. Both games and technologies are counter-irritants or ways of adjusting to the stress of the specialised actions that occur in any social group. As extensions of the popular response to the workaday stress, games become faithful models of a

culture. They incorporate both the action and the reaction of whole populations in a single dynamic image (McLuhan, 2001, p. 235).

This eloquent description identifies the many beneficial outcomes that can be attained by practising with the games. The following sections will discuss various aspects of video game playing in detail.

Applications of Video Games

It has been established that games are important tools in the learning process. Porter (1995) indicates that games are among the most natural of human activities and that they develop specific skills and perspectives in their participants. The video games have been described as "a window onto a new kind of intimacy with machines that is characteristic of the nascent computer culture" (Turkle, 1984, p. 66). They are arguably one of the most visible products of advances in computer microchip technology in the last decade (Lin & Lepper, 1987). Proponents of the games view them as a source of learning and entertainment as a result of which the term 'edutainment' has been coined to reflect their dual nature.

Computer Literacy

It is believed that video games combine two ingredients - intrinsic motivation and computer-based interaction, which make them potentially the most powerful educational tools ever invented (Loftus & Loftus, 1983). Proponents of the games have also argued that the strong reinforcement properties of the games should be viewed as a potentially useful tool transferable to educational settings (Buckalew & Buckalew, 1983). Indeed, computer games are being used more often in schools (Rheingold, 1983) now than previously and have been used to promote learning in areas such as reading speed and ability (Radencich, 1984). Among adult students, Greenfield, Camaioni, Ercolani, Weiss, Lauber, and Perucchini (1994) reported a transfer of cognitive skills arising from practice on computer games to regular computer use for scientific-technical purposes. Indeed, several researchers have also demonstrated the correlation between video game playing and computer literacy.

Greenfield (1993) reveals "among all the forms of computer technology, the video game touches most directly a majority of people" (p. 167). Markel and Oski (1996) have suggested that an added benefit of playing computer-based games is that they encourage the child to become computer-literate. Research also shows that cognitive skills acquired through video game playing could be useful in dealing with computers (Compaine, 1983; Greenfield, 1989,1993; Lepper, 1985). This educational value in transfer of computer skills is essential, as computer-related equipment have penetrated many areas of our daily lives in the present time.

The extent to which computers have penetrated into our homes is constantly increasing. In Australia, the proportion of households with access to a computer at home has risen from 44 per cent in 1998 to 66 per cent in 2003 (Australian Bureau of Statistics, 2004). Amongst adults, young adults in the age group of 18 – 24 years (who are the focus of the current research) have the highest participation rate of computer usage at 89 per cent (Australian Bureau of Statistics, 2002).

There is a concern that girls have a lackadaisical attitude towards computers and that this outlook may influence their competence with computer technology (Subrahmanyam & Greenfield, 1994). However, recent research shows that video games have the potential to enhance interest in computers, especially among girls, when the games have the capacity to allure them (Gorriz & Medina, 2000). This potential should then be developed as previous research has shown that video games are one of the first opportunities children have to interact with computer technology (Greenfield, Brannon, & Lohr, 1994; Smith & Stander, 1981).

As early as 1985, Lepper suggested that in a few years, most of the children's education would take place via the computer; video games possess the potential for imparting informal education vital to deal with computer technology (Greenfield et al., 1994). Thus, video games serve as a bridge to the larger computer culture (Turkle, 1984) and beyond. Indeed, these findings further warrant the investigation of the video game as an important technological medium with educational implications.

Research Tool

The video games have other implications as well. In relation to research, there is an increasing need to study human behaviour "effectively;" researchers aim to investigate their participants in as natural an environment as feasible in order to maintain ecological validity. Video games offer an ideal environment for many reasons: the games themselves are naturally motivating and engaging that subjects forget laboratory settings altogether (Porter, 1991); they are "intrinsically motivating" – that is, people enjoy engaging in interaction with the games because of attributes of the games themselves rather than extrinsic factors, such as monetary rewards, fame, fortune or achievement (Lepper, 1985); they have a capacity to surreptitiously record many collateral measures of performance, without requiring other tools of measurement (Donchin, 1995); they also allow simulations of situations or environments in which participants' skills can be safely tested without the risk of major accidents or negative consequences to themselves.

Frensch and Sternberg (1991) have further highlighted four elements of the games that make them attractive to researchers including: a) the means to decompose games into sequences of observable moves so that the researcher can gain insight into a "continuous problem-solving process" (p. 343); b) the well-defined rules by which games are governed to ensure that the number of possible moves at any time is limited, which enables the measurement of the space within which a player might operate at any given time; c) high external validity of the video game that presents virtual experience which is in many respects similar to real-life situations; and, d) the feature of games to be "complex and nondeterministic," which means that a player's move is not completely determined by previous moves, but rather on his or her goals and intentions (Johnson-Laird cited in Frensch & Sternberg, 1991).

Hedden (1997) has also extensively elaborated on the use of computer games as automated data collectors for the study of human-computer interaction. Quinn (cited in Hedden, 1997) believes that the motivational aspect makes tasks embedded in a "thematically coherent framework" more likely to resemble real tasks and thus further validate the results. Overall, it is clear that knowledge is best acquired when the task is perceived as interesting and enjoyable (Greenfield, 1994; Hedden, 1997). Therefore, the games have been identified as valuable research tools because they "represent holistic, meaningful, and natural human activity" (Porter, 1995, p. 229) that offer unique opportunities to analyse human behaviour.

Administrative Skills

Some video games that have been developed nurture specific skills, such as municipal administration and health administration. For example, 'SimCity 2000' requires the gamer to build an entire city through simulation by starting from the initial foundation-laying stages to building houses, communities, shopping malls and so on. The game is constructed in a manner such that the decisions of the player have consequences on the livability of the city he or she has built (Pesce, 2000). Another game that also has educational value is 'SimHealth'. This game was designed to demonstrate the complexities, difficulties, and pitfalls of health care in America (Pesce, 2000); it thus showed how a computer game "could be a powerful tool for examining the interconnected array of issues confronting a society" (p. 174).

Therapeutic Aid

It has been reported that video and computer games such as Nintendo, Atari, and Sega have been added to the inventory of common card and board games for use in play therapy (Gardner, 1993). These electronic games have been found to be an "excellent ice-breaker and rapport-builder" (Gardner, 1993, p. 273) and act as a medium of mutual enjoyment and understanding to further the process of therapy. In fact, they were found to be the most useful factors in a child's improvement in therapy. Further therapeutic effects include increased attention span and motivation (Butterfield, 1983) and the enhancement of cognitive skills (Greenfield, 1983). The above findings therefore suggest that the games can be viable therapeutic tools.

Researchers (Clark et al., 1987) have also demonstrated the applicability of the games as an intervention tool to reverse the decline of speed response among the elderly. Participants (aged 57 to 83 years) who practiced with video games were faster on the two-choice reaction time task at posttest compared to the control group. In addition, the elderly perceived the task as novel and challenging and can therefore be regarded as an effective intervention tool (Clark et al., 1987). These findings, along with those by Gardner (1993) demonstrate that video games can be feasible intervention tools in the treatment of the young and the elderly.

There are also suggestions for the use of games in psychological assessment because they are more interesting and applicable to different groups of individuals (Ryan, 1994) as well as training aids to some cognitive and perceptual-motor disorders (Griffiths, 1991). Thus Johnson (1993) aptly reiterated "the computer age is here; we might do well to learn what it has to offer counsellors and psychologists" (p. 286).

Cognitive Effects of Video Games

"The playing of video games and their counterparts, arcade and computer games, is a ubiquitous feature of the culture of today's children and youth. Yet very little is known about the impact of playing video games on cognitive skills" (Okagaki & Frensch, 1994, p. 54).

The above statement reflects the need to further enhance the existing knowledge on issues concerning video game playing and its connotations on cognitive processes.

Researchers have been investigating the development of skills through game playing since the early 1980's and one of the first such propositions was put forward by Greenfield (1984). She indicated that cognitive processes most often depend on interacting with either other people or cultural artifacts. She reiterated, "video games are cultural artifacts that require and develop a particular set of cognitive skills; they are a cultural instrument of cognitive socialization" (Greenfield, 1994, p. 5). Researchers have demonstrated the improvement of a range of cognitive skills through the use of video games. These skills will be elaborated on in the following sections.

Variety of Cognitive Skills

The games are characteristic of a wide variety of social and cognitive skills that can be developed through playing diverse types of games. Game playing has been found to enhance both individual interpersonal interaction and group effectiveness (Cohen, Fink, Gadon, & Willits, 1980; Gardner, 1993). According to Gardner (1993), cognitive skills that can be enhanced include: (a) problem-solving strategies (e.g., *Legend of Zelda*), (b) the ability to perceive and recall subtle cues as well as foresee consequences of behaviour and act on past consequences (e.g., *Super Mario Brothers*), (c) eye-hand coordination (also Butterfield, 1983; Donchin, 1983) (most games, especially, *Gradius, Robo Cop*); d) the release of aggression and control (e.g., *Kung Fu*), (e) the simulation of sports (e.g., *Techno Baseball, Football, Soccer,* etc.), (f) the cognitive involvement in the recall of factual information (e.g., *Jeopardy*), and, g) the social enjoyment in the coordination and cooperation of succeeding in the game (e.g., *Gyromite*).

The games also teach specific skills in spatial visualization or mathematics (Butterfield, 1983; Donchin, 1983) or act as a form or preparation for, or initiation into, the more cognitively demanding world of computer technology (Gabel, 1983; Greenfield, 1994). Turkle (1984) indicates that the games demand skills that are complex and differentiated, and that working out the game strategy involves a process of deciphering the logic of the game, of understanding the intent of the game's designer, of achieving a "meeting of the minds" with the program. In addition, Porter (1995) argues that games develop specific skills, such as mental schemata, and perspectives among participants. Thus it is evident that the games offer rich learning opportunities.

Spatial Skills

Video games have the capacity to improve other skills including spatial skills. Okagaki and Frensch (1994) demonstrated the potential to improve performance on spatial development measures through video game playing after participants played *Tetris* for a total of six hours across many sessions. They found that playing *Tetris* improved both mental rotation time and spatial visualization skill amongst males and females. Similarly, De Lisi and Wolford (2002) found that spatial abilities could be enhanced through computer game playing.

Subrahmanyam and Greenfield (1994) also investigated spatial skills among boys and girls before and after practice with a computer game. A significant difference was found on spatial performance between those who practiced with the computer game and those who practiced with a computerized word game. Overall, both boys and girls in the study showed an improvement on spatial scores; however, a greater effect was evidenced amongst the boys. The difference was most evident among children who initially had low spatial skills, while those who already had high spatial skills remained at the same level. This finding could be related to the limited benefit of practice for experienced individuals (the ceiling effect).

Indeed Gagnon (1985) reports that a substantial effect of experimental practice will be witnessed in the less experienced group only. The more experienced players will not significantly improve their skills beyond the level of current attainment through the large amounts of practice they would have already received in the real world (Greenfield, DeWinstanley, Kilpatrick, & Kaye, 1994), as they would have reached the ceiling level. Therefore, a greater effect of the treatment would be expected in the novice group compared to the expert group.

Reaction Time Task Performance

Dustman et al. (1992) inferred that video game playing could improve efficiency of cell assemblies (in the central nervous system), which are stimulated by visuomotor activities that are common to both video game playing and reaction-time tasks. The results of their study on elderly individuals showed reaction time (RT) responses to be significantly faster at posttest for the group that received video game practice. In a similar finding, Clark et al. (1987) demonstrated that elderly participants who practiced with video games improved not only on the video game scores, but also in a component of information processing, namely, response selection. In their study, the elderly in the experimental group played two video games - *Pac Man* and *Donkey Kong* - over a seven-week period; the control group did not play any game. Comparison of the pre- and posttest times on the RT task between those who practiced with the games and those who did not revealed that video game playing positively affected the time taken to select a response. In other words, seniors who played video games were faster in their RT performance, thus indicating an improvement in their response selection (Clark et al., 1987). In effect, enhancement in RT results indicates that the central nervous system can be modified by activation procedures such as playing a video game, which suggests that decline in speeded processing can be reversed (Clark et al., 1987; Dustman et al., 1992).

Faster RT responses have also been recorded for younger video game players. Mc Sweign, Pemberton, and O'Banion (1988) and Yuji (1996) found that children who played computer games extensively had a faster mean RT than those who played less often. Similarly, Orosy-Fildes and Allan (1989) conducted a study to investigate the effects of practice with video games on a RT task amongst young adults. Their results revealed that even a 15-minute practice with video games could improve RT performance. They found the RT of the experimental group to decrease significantly after practice compared to the control group that showed no difference between pre- and post mean reaction times. These findings suggest that video games possess the potential to develop important information-processing skills.

Multimodal Perceptual Skills

Based on their findings, Braun and Giroux (1989) identified that the video game player is required to constantly and simultaneously process multimodal perceptual information and respond to it with coordinated motor sequences on the basis of cognitive modelling, executive planning, and evaluation of ongoing feed back. They therefore concluded that the task demands of video games varied cognitively, perceptually and motorically.

Kennedy, Bittner Jr., and Jones (1981) affirmed the feasibility of a video game (*Atari's Air Combat Maneuvering*) as a means of a reliable pursuit-tracking task. They also envisaged the functionality of video games to include predictive testing, training, and evaluation of performance, further demonstrating the development of a range of uses of video games.

Attentional Skills

Formal studies on the relevance of video game training to manage attentional skills have been conducted in the area of flight performance. Some of the qualities of video games that add to their value as a training medium include their capacity to engage the player, their ready availability, their inexpensiveness, and their similarity with flight equipment in requiring efficient control and management of attention under a high task load (Baker, Prince, Shrestha, Oser, & Salas, 1993; Gopher, Weil, & Bareket, 1994).

In an extensive study conducted by Gopher et al. (1994), it was found that skills acquired through computer game practice could transfer to flight performance. The researchers compared flight performance scores of two groups of cadets, only one of which received 10 hours of training with a computer game. They provide three arguments why the computer game would present a useful training context for developing flight-relevant skills – particularly those related to the control of attention and coping with high task load. One claim is that attention control is an important element in the acquisition of flight skills; secondly, such control can be considered a skill, which can be improved by training; and thirdly, the context provided by the selected computer game is relevant to the training of flight skills. Evidence for the transfer of game training to actual flight was found when the game group performed significantly better on flight performance compared to the group that did not receive any game practice. Furthermore, the game group was higher on 25 of the 33 flight scores that were recorded. Thus the authors clearly illustrated that cadets who practiced with the computer game showed a clear advantage on flight performance compared to those who did not receive any training.

Many of the skills achieved through game playing can transfer directly to real-life activities (Broadbent, 1986; Piaget, 1970), including performance in sports such as basketball, ordinary life safety skills such as driving a car, or operating different heavy equipment, where skilled performance requires the monitoring of multiple stimuli (Greenfield, DeWinstanley et al., 1994).

Skills of Divided Attention

The study by Greenfield, DeWinstanley et al. (1994) showed that practice with video games could lead to a transfer of divided attention strategies to a new task. The researchers investigated the role of video games in developing strategies for tracking events (targets) at multiple locations on a screen. When performance between expert video game players and novices was compared, it was found that the experts had faster response times than novices at both high and low probability positions of an icon. In other words, what differentiated the expert and novice video game players is their ability to respond quickly to the positioning of a target when the target occurrence is low. Furthermore, the researchers found that five hours of playing an action arcade game also improved strategies for dividing attention at the low probability position of the target only. It is suggesetd that improvement in such skills could aid the provision of informal education for occupations that demand skills in divided attention including instrument flying, military activities, and air traffic control (Greenfield, DeWinstanley et al., 1994).

In a recent study, Green and Bavelier (2003) established changes in different aspects of visual attention when performance was compared between habitual video-game players and non-video-game players. They suggested that an action video game has the potential to modify selective visual attention.

It has also been observed that video game players are constantly monitoring several targets appearing simultaneously at several locations on the video screen (Gagnon, 1985; Greenfield, 1984) as well as controlling the different buttons on the controller *and* moving the joystick in the appropriate directions simultaneously. In addition to these actions, the players are also able to converse logically. Anecdotal evidence also abounds from parents who provided instructions to their child who was engrossed in playing a video game and contrary to their presumption that the child did not register their instruction, the child carried out all the instructions upon game completion to the parents' bewilderment. Such reports suggest that video games surreptitiously allow players to develop strategies to attend to several tasks simultaneously.

Other researchers have established a high correlation between performance on a flight simulator configured for aircraft carrier landing and performance on the Atari home video game *Air Combat Maneuvering* (Lintern & Kennedy, 1984). Greenfield et al. (1994) stated that pilots usually have to keep track of a lot of different instruments - for example, a row of six engine dials, and this is very similar to a video game. Thus one reason for the correlation obtained in the Lintern and Kennedy (1984) study might be due to the degree of similarity in skill between the video game and the flight simulator.

The findings of the above studies indicate the possibilities for developing divided attention skills through video game playing. However, as research in this area is limited and there are methodological shortcomings in previous studies, it is essential that further investigations be conducted in this area to fully establish and realise the potential of video games to develop such important skills.

Memory Skills

There have been few attempts to use video games for the training of memory. Ryan (1994) investigated the role of a computer game, *Memory for Goblins,* to assess and train working memory skills based on her earlier findings from 1986. She implemented the game as a computer counterpart to a test of working memory, i.e., the Counting Span task, which requires the participant to count coloured dots on a sequence of cards. In this task, the participant is required to keep track of the previously counted values while subsequent counting occurs. In the computer game version, the screen showed goblins intermingled with squares, and the player's task was to count the goblins and type in the appropriate number. Ryan found that the older adults perceived the game as novel and interesting and that the game could serve as a useful assessment tool. She also suggests that practice with the game could have implications for the training of working memory, especially among the elderly.

In studies on the neuro-cognitive effects of video games, it has recently been shown that playing *Tetris* assists in building memories and activating certain brain areas that were previously inactive (Helmuth, 2000). In the study conducted at the Harvard Medical School, researchers found that people who learned to play *Tetris* only recently had vivid images of the game pieces floating before their eyes as they fell asleep – the researchers indicate that this phenomenon is critical for consolidating memories. More surprisingly, the investigators found the images to appear even to people with amnesia who had played the game. Although these people had no recollection of actually having played the game, they reported visualizing the pieces of the games during their sleep. Such findings suggest that video game playing could assist in memory development in specific ways.

There are some similarities between encoding and retrieval processes in experimental situations (for example, in free and cued recall) and encoding and retrieval situations that naturally occur during the playing of a video game. For example, in an experimental situation, a participant would be required to encode the information presented for later recall. Similarly, while playing a video game, the player has to constantly encode a range of information for use later in the game. However, how the constant practice of encoding and retrieval in a gaming situation might transfer to other tasks has not been researched. Thus the dearth of studies in this promising area necessitates the need for research in the area of video games and its influence on memory.

Video Game Playing and Females

"The idea that women don't like to play games... is an unfortunate stereotype that lingers from the early days of the industry when most gamers were boys. It's like saying women don't like to play sports .... we are working to educate others on this matter..." (Lowenstein, 2000, p. 1).

Numerous studies have indicated that there are gender differences with regard to frequency of game play and the capacity to meet some of the challenges the games present (Braun & Giroux, 1989; Durkin, 1995; Greenfield, 1994; Kaplan & Kaplan, 1981; Loftus & Loftus, 1983; Wark, 1994). Traditionally, boys are more likely to play video games and do so more frequently (Braun & Giroux, 1989; Greenfield, 1994). In contrast, girls play for shorter amounts of time, fail to develop the same level of skills as boys, and show less interest in video game playing (Durkin, 1995). However this trend is changing.

Recent reports indicate that females are becoming a significant game-playing group and that they are not far behind in accounting for the interest, frequency, and number of hours video games are played. From their studies among adolescents, Griffiths and Hunt (1995) and Colwell et al. (1995) found no differences between males and females with regard to who played more computer games. Similarly, The Interactive Digital Software Association in the USA has revealed that a large proportion of the game playing population includes women (Lowenstein, 2000). It also found that 30 per cent of video game players who play more than 10 hours a week are women. Unfortunately, little Australian research provides a comparative account of game playing habits among women. However it has been suggested that much of the gender gap has closed as a result of increased participation of girls and women in online gaming and console playing (Marshall, 2002).

The shift in female interest in games could be a result of the availability of a different genre of video games in recent years - a genre better suited to the female game playing interest. One game that has proven popular in recent times is *Barbie Fashion Designer*, which is a cyber creation of the Barbie doll. It sold 500,000 copies in two months, which is more than twice the previous monthly sales record in the computer game market (Maisel, 1997).

In spite of the shifting trend in interest in playing games, a number of researchers agree that video games in general have a greater appeal for boys than girls and that most themes of the games are action-oriented, to which boys are more likely to be attracted. In fact, action is recognized as a male characteristic according to research on responses to television commercials with different formal features (Braun, Goupil, Giroux, Chagnon, 1986; Griffiths & Hunt, 1995; Gorriz & Medina, 2000; Morlock, Yando, & Nigolean, 1985; Welch, Huston-Stein, Wright, & Plehal, 1979). Hence the genre of action video game by its very nature has greater appeal for boys than girls (Greenfield, 1994; Kiesler, Sproull, & Eccles, 1983; Provenzo, 1991). However, the evidence is contradictory or not consistent regarding preference of violent themes between boys and girls. While Greenfield, DeWinstanley et al. (1994) believe that boys prefer a violent game theme and that girls do not, Braun and Giroux (1989) did not find any sex difference in the preference of violent games.

Some sex differences in video game playing frequency and interest could be related to the level of acquired game playing skills and proficiency. In the study by

Greenfield, Camaioni et al. (1994), male university students showed higher levels of video game playing skills both initially and after several hours of practice than did female students. Similarly, male students mastered the game whereas female students did not - even though they played more games in their attempts to reach a criterion to attain a high score (Greenfield, DeWinstanley et al., 1994).

There has been some effort to account for the better performance by males on video games. Subrahmanyam and Greenfield (1994) argue that boys had greater experience with games prior to the study and it may be this familiarity that gave them a greater readiness to acquire new skills from computer activities. Another factor could be that males take a more trial and error approach to the games than females (Greenfield, 1994). Smith and Stander (1981) reported this in anthropology students who were first-time users of a computer system. Sex differences in the ability to apply logical and strategic planning skills to video game playing may also explain sex differences in learning to play video games (Mandinach & Corno, 1985).

Another factor could be due to sex differences in spatial skills: all the three studies that measured spatial skills in relation to video game playing found sex differences in favour of males (Greenfield, DeWinstanley et al., 1994; Okagaki & Frensch, 1994; Subrahmanyam & Greenfield, 1994). An alternative explanation of the skill deficit might be that girls may just feel uncomfortable in the arcade arena where males are present in greater numbers (Kiesler et al., 1983). Indeed, for several reasons, it is clear that males do have more video game experience than females both in childhood (Subrahmanyam & Greenfield, 1994) and adulthood (Greenfield, Brannon et al., 1994; Greenfield, DeWinstanley et al., 1994b).

Some reasons for the sex difference could lie in the fact that the female "market" has largely been ignored with the majority of game developers being male, which has indisputably influenced production decisions about the types of video games (Lowenstein, 2000). To confound the issue of sex imbalance in video game playing, boys can identify with the protagonist in video games more easily than girls do. There are many more male characters (Braun & Giroux, 1989) and female characters rarely assume a leading role (Kiesler et al., 1983) or cater for the stereotypical male ideals of "female" characters. That is, ideals of female characters are often portrayed as either the "weaker sex" constantly in need of aid or assistance (Provenzo, 1991) or competent or even strong characters that are aesthetically and visually appealing (e.g., Lara Croft in Tomb Raider) from the viewpoint of the male juvenile game player. This portrayal does not to appeal to women (Cassell & Jenkins, 1999.). Therefore the majority of products cater to the perceived interests of male adolescents to the detriment of their female peers (Durkin, 1995).

On the other hand, games based on fun characteristics, less action and more adventure and which are less demanding in terms of motor skill requirement to achieve a high score, such as Pac-Man and Super Mario Brothers have been found to have greater appeal to female video game players (Cuppitt & Stockbridge, 1996; Griffiths & Hunt, 1995; Gutman, 1983; Morlock et al., 1985). These findings suggest that females have a different set of preferences in software design and it is therefore important to transfer female play patterns from the physical environment to the virtual if their gaming needs are to be fulfilled (Maisel, 1997).

Although most studies show a large gender gap in video game playing skills, male video game players enter the experiment with a higher acquired expertise level obtained through prior exposure to video games (Greenfield, DeWinstanley et al., 1994) compared to females who enter without it. The over-representation of male video game players is further confounded by the fact research includes a greater proportion of men than women in the sample. Most studies cite the reason of the lack of interest by women to participate in such a study for this imbalance in the sample composition. However, it is unclear as to why conditions for female participants to become more involved in such research have not been made viable. Aptly, Greenfield (1994) thus emphasises the need for a concerted effort to develop games that appeal to girls.

Constructing an Appropriate Game

It is essential that video game manufacturers and designers create games with maximum potential to develop important skills while retaining the fun themes. Based on his findings on the important criteria for designing enjoyable and educational programs, Malone (1981) suggested the following points on five themes to consider when constructing video games. The themes relate to the different arenas that would arouse the interest of the player in the game; they are presented in Table 2:

Table 2

Themes to consider while constructing video games

Theme	Criteria
Goal	Does the activity have a clear goal? If not, is it easy for students to determine goals of appropriate difficulty for themselves? Are the goals personally meaningful?
Uncertain outcome	Does the program have a variable difficulty level, which is determined by the student or determined automatically, depending on the students' skill? Does the activity have multiple goal levels which incorporate scorekeeping and speeded responses? Does the program include randomness? Does the program include hidden information selectively revealed?
Fantasy	Does the program include an emotionally appealing fantasy? Is the fantasy intrinsically related to the skill learned in the activity? Does the fantasy provide a useful metaphor?
Curiosity	Are the audio and visual effects present as: decoration; to enhance fantasy; as a reward; or as a representation system?
Cognitive curiosity	Does the program include surprises? Does the program include constructive feedback?

From: "What makes computer games fun?" by T.W. Malone, 1981, BYTE, 258-277.

Apart from consideration for creating educational and entertaining software programs, game creators should also develop games that adequately cater to the needs of both males and females. Currently, it appears that manufacturers are of the notion that it is not important to design games specifically for the female population as the sales figures for this group is low. However, the market for video games directed to this segment of the market is surely and steadily increasing (Marshall, 2002). With research demonstrating the likes of the girls to be different to those of boys (Goldstein, 1994; Kafai, 1996; Kafai, 1998; Provenzo, 1991), although there might be some common interests (Kafai, 1998), especially after repeated play exposure (Greenfield & Cocking, 1996), it is clearly essential that video games need to be refined in order to reach the widest audience. This area of research has been neglected and is certainly worthy of academic attention (Griffiths & Hunt, 1995).

Classification of Games

Electronic video games are available for four general hardware systems, including handheld, home video, arcade, and personal computer. There are no clearly defined distinctions in the use of terminologies between 'computer games', 'video games' and 'arcade games.' The terms 'video games' and 'computer games' have been used inter-changeably in the research literature. However, Nawrocki and Winner (1983) regard personal computer games differently from home video games in two respects: personal computers have a general purpose with gaming as a software adjunct, and, a large number of strategic and planning games are generally absent from video game systems. Roberts, Foehr, Rideout, and Brodie (1999) refer to arcade games, games for game systems such as Nintendo or Playstation, and stand-alone games or interactive toys as 'video games.' On the other hand, they classify games that can be downloaded or played on a personal computer as 'computer games.' Besides, 'arcade games' generally refer to a video game played in arcades and often involves multiple players.

For a more general classification, Subrahmanyam, Kraut, Greenfield, and Gross (2001) use the term 'interactive games' to cover both types of platforms. One differentiating and relevant factor applies to the games that are played in the arcade and those played on home video game systems. Greenfield (1993) points out that "games originating for home game systems, such as the popular role-playing adventure games, require much more complex problem-solving and strategy, with less emphasis on speed" (p. 163) compared to arcade games.

For the purposes of the current study, the term 'video game' will be adopted to explain the effects of the games, however, the findings do not preclude the influence of 'computer games' and 'arcade games' on the different cognitive processes under investigation in the present study.

There are various genres that are used to describe the nature of the games. Some of the most common genres that have been employed in studies (for e.g., Office of Film and Literature Classification, 2003; Griffiths, 1993) are provided in Table 3.

Table 3

Genres of Video and Computer Games

No.	Genre	Description
1.	Adventure	Fantasy games in which the player can escape to other worlds and take on new identities (e.g., Banjo Kazooie, Super Mario Brothers, etc.)
2.	Action	Games involve shooting, killing, and destroying using weapons or game character (e.g., Street Fighter, Legend of Zelda)
3.	Sports	These games simulate sports such as tennis, gold, athletics and so forth (e.g., Super Tennis, NBA Basketball, etc.)
4.	Racers	As the name suggests, the games involve racing games such as car or motorbike races (e.g., Top Gear, Grand Theft Auto)
5.	Puzzles	These games mostly involve mazes and require active thinking (e.g., Tetris, Pac-Man)
6.	Educational	Most of these games are constructive in nature, in that they aid the development of particular skills such as architectural, or health administration (e.g., Sim City, Sim Health)

From: "*Guidelines for the classification of films and computer games*," by the Office of Film and Literature Classification, 2003 (Electronic resource) NSW: Office of Film and Literature Classification, and "Are computer games bad for children?" by M. Griffiths, 1993, *The Psychologist: Bulletin of the British Psychological Society, 6.*

Games are also classified based on their content and appropriateness for different age groups. Usually, each country has its own independent rating board that governs the ratings for new video games. The games are usually categorised on the basis of level of violence, their educational value, or sexual reference and coarse language. In Australia, the Office of Film and Literature Classification provides ratings for each newly released game. These ratings and descriptions of the ratings are presented in Table 4.

Table 4

Australian Ratings for Video and Computer Games

No.	Rating	Description
1.	General (All Ages)	This category of games is suitable for persons of all ages. The product is suitable for the youngest child and should not require parental supervision.
2.	Parental Guidance/ General (8 years and over)	This classification applies to games that are considered suitable for children eight years and over. This type of material would contain elements which might disturb or distress very young children. Such elements could include: (a) depictions of unrealistic or stylised violence even where these are considered mild, (b) mild horror or potentially frightening fantasy characters or situations, and, (c) the mildest expletives, but only if infrequent.
3.	Mature/ Mature + (15 years and over)	"Mature" material is considered suitable for persons aged 15 years and over. Elements which could be considered harmful to those under 15 years include: (a) depictions of realistic violence of low intensity (e.g., punches, kicks, and blows), (b) supernatural or horror scenarios, but not if graphic or impactful, (c) mild sexual references, and, (d) low level coarse language, but not if excessive.

Table 4 (continued).

No.	Rating	Description
4.	MA – Mature Accompanied/ MA (15 years and over) – Mature Restricted	Although this classification initially appears to be similar to the previous one (Mature), the differences are that games classified "MA" include further strong depictions of violence, horror, and sex. Such games are restricted to persons aged 15 years and over, and the nature of the games would include: (a) depictions of realistic violence of medium intensity (e.g., impactful punches, kicks, blows, and bloodshed), (b) graphic or impactful supernatural or horror scenarios, (c) strong sexual references, (d) use of frequent crude language, but not if excessive, unduly assaultative, or sexually explicit, and, (e) nudity, including genital detail, but only if there is a 'bona fide' educational, medical, or community health purpose.
5.	RC – Refused Classification	Games classified "RC" are not permitted to be sold, hired, exhibited, displayed, demonstrated, or advertised. Games are refused classification because of the extreme depictions of violence, sex, language, and other features such as paedophile activity, encouraging abuse of drugs, etc. in the game.

From: "*Guidelines for the classification of films and computer games*," by the Office of Film and Literature Classification, 2003 (Electronic resource) NSW: Office of Film and Literature Classification.

Table 5 presents the ratings by the Entertainment Software Rating Board (ESRB) (ESRB, 2002), an independent, self-regulatory entity in the United States that provides comprehensive support services to companies in the interactive entertainment software industry. The two rating systems are mainly different in the age group permitted to play the 'Mature' category games (the Australian system permits persons 15 years and over to play such games, while the American system permits persons 17 years and over to play these games) and in the 'Refused Classification' category that only the Australian system employs.

Table 5
American Ratings for Video and Computer Games

No.	Rating	Description
1.	EC – Early Childhood	Titles rated "EC" have content that may be suitable for children aged three years and more, and do not contain any material that parents would find inappropriate.
2.	E – Everyone	Games rated "E" have content that may be suitable for persons aged six years and more. They may contain minimal violence, some comic mischief (for example, slapstick comedy), or some crude language.
3.	T – Teen	Titles rated "T" have content that may be suitable for persons aged 13 years and more. Titles in this category may contain violent content, mild or strong language, and/or suggestive themes.
4.	M – Mature	Games rated "M" have content that may be suitable for persons aged 17 years and more. These products may include more intense violence or language than products in the Teen (T) category. In addition, these titles may also include mature sexual themes
5.	AO – Adults Only	Games that have content suitable only for adults are rated "AO". These products may include graphic depictions of sex and/or violence. Adults Only products have restrictions on sale and not permitted to be sold or rented to persons under the age of 18.
6.	RP – Rating Pending	This rating applies to games that have been submitted to the ESRB and are awaiting final rating.

From "Ratings for video and computer games" by the ESRB. Retrieved from www.esrb.org in 6 June 2002.

In the current investigation, every effort has been made to incorporate a video game that appealed to females. The selection of an appropriate game was based on survey findings of the Australian Broadcasting Authority and the Office of Film and Literature Classification (Cupitt & Stockbridge, 1996), wherein the games preferred by both sexes were listed. The report found that the majority of girls liked 'Mario Brothers', followed by 'Sonic the Hedgehog', 'Tetris' as well as 'Alex the Kidd' and 'Solitaire' which were preferred equally. An attempt was also made to include a popular, interesting, challenging, enjoyable, and yet non-violent video game. Further details regarding this selection process are presented in the Method section.

In summary, this chapter has discussed the features of video games and outlined the effects of video game playing on social and cognitive skills. The influence of video games on both sexes has also been examined and finally, the different rating systems for video and computer games have been provided. The findings of previous studies in the field provide both an impetus and the rationale for the conduct of the current study.

ATTENTION

"Prepared am I to press my key, so little shown to me,
With brimming short-term memory, in great uncertainty,
Attention and Performance is my savior, my behavior,
My S-R relation and Association for distinguished Study!" (Bouma & Bouwhis, 1984, p. xix).

This verse is a part of the Attention and Performance Hymn that was sung to celebrate the tenth Attention and Performance Symposium. A song to celebrate a cognitive phenomenon? It is the exciting nature of 'attention' that leads one to revel in its study. For a long time, the study of 'attention' and its related concepts has been a fascinating participant matter for psychologists. This chapter will review the mechanism of attention, some dominant theories that elucidate the concept of attention, and some of its main features.

The Mechanism of Attention

'Attention' has been conceptualized in various ways ever since its research began in the 1950s. There has been a tremendous surge in knowledge gathered regarding the concept; however, many researchers seem to ponder what attention really is. In spite of this quandary, it is interesting to note that William James (1890) made the confident assertion, "everyone knows what attention is" (p. 403) over a hundred years ago. He eloquently elaborated that:

> It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others. (James, 1890, pp. 403-404).

Since James' writing, the field of psychology has broadly expanded to develop several theories and models of attention. However, although the extant literature provides extensive construction of theories, it seldom clarifies the concept of attention. This lack of clarity in defining attention may indicate the difficulty in explaining briefly or simply what attention encompasses. In fact, the diversity of explanations that have been offered by researchers include the description by Skinner (1953) that attention is a functional relationship between stimuli and responses; Gibson and Rader (1979) defined attention as "perceiving in relation to a goal, internally or externally motivated" (p. 2) and Spelke, Hirst, and Neisser (1976) suggested that "attention be regarded as a matter of extracting meaning from the world, and perceiving the significance of events" (p. 228). They elaborated that "attention is involved in comprehending what one reads or hears, or in following any meaningful event over time" (p. 228).

According to the dictionary, attention is the "concentration of the mind upon an object or maximal integration of the higher mental processes" (The Macquarie Dictionary, 2001). A modern textbook of cognitive psychology simply defines attention as a concentration of mental activity (Matlin, 1998). All the varied descriptions have enabled the understanding of a broad and intriguing concept.

The work on attention has been divided into three phases (Posner, 1993). Initially, in the 1950s and 1960s, research focused on human performance, and on the concept of 'the human as a single channel processor'. In the 1970s and early 1980s the field of study came to be known as 'Cognition' wherein researchers examined internal representations, automatic and controlled processes, and strategies for focusing and dividing attention. By the mid 1980s, the name "Cognitive Neuroscience" was given to account for the biological, neuropsychological and computing aspects that were being encompassed into the research on attention. Posner points out that despite a shift of major emphasis, all the different lines of research have been studied in the 1990s and beyond.

The modern era of attention research was introduced by Donald Broadbent (1958) who theorised attention to be the result of a limited-capacity information-processing system. The Human Information-Processing Approach introduced by Broadbent in his influential book 'Perception and Communication' "proposed a simple, elegant, and intuitively appealing model for attention" (Moray, 1993, p. 112).

The essential notion of Broadbent's filter model of attention is that the perceptual and cognitive capabilities of the human observer could not simultaneously handle the many sensations the world is made of. In order for humans to cope effectively with the bombarding stimuli, they are to pay selective attention to some of the cues and tune out the others. This idea guided his 'filter model.'

Some of the other early systematic studies on attention were conducted by Cherry (1953) who focused on auditory attention and lay the foundation for an early selection theory. He conducted experiments on a dichotic listening task, where participants were required to repeat a message that was presented through one ear and shadow the message that was presented through the other ear. Cherry (1953) and

Moray (1959) discovered that very little about the unattended message is processed in a shadowing task. Similarly, an analogy is often made between a dichotic listening task and tuning into a particular message (such as one's name) while at a cocktail party and filtering out all other irrelevant information in the face of the distractions of other conversations. This is also popularly referred to as the cocktail party phenomenon.

Models of Attention

Cherry's work initiated further studies in the area of selective attention. Over the past five decades, several theories and models of different aspects of attention have been established. However, it is not the primary scope of this thesis to encompass all aspects of the theories of attention. Therefore, only some of the significant models will be discussed here. Some of the early theories that were postulated include those by Broadbent (1958), Treisman (1964), and Deutsch and Deutsch (1963). There were further theories proposed by Shiffrin and Schneider (1977) and Treisman and Gelade (1980). Theories that were formulated much later include Bundesen's (1990) theory of visual attention (TVA) and the CODE (Contour Detection) theory of visual attention (CTVA) (Logan, 1996).

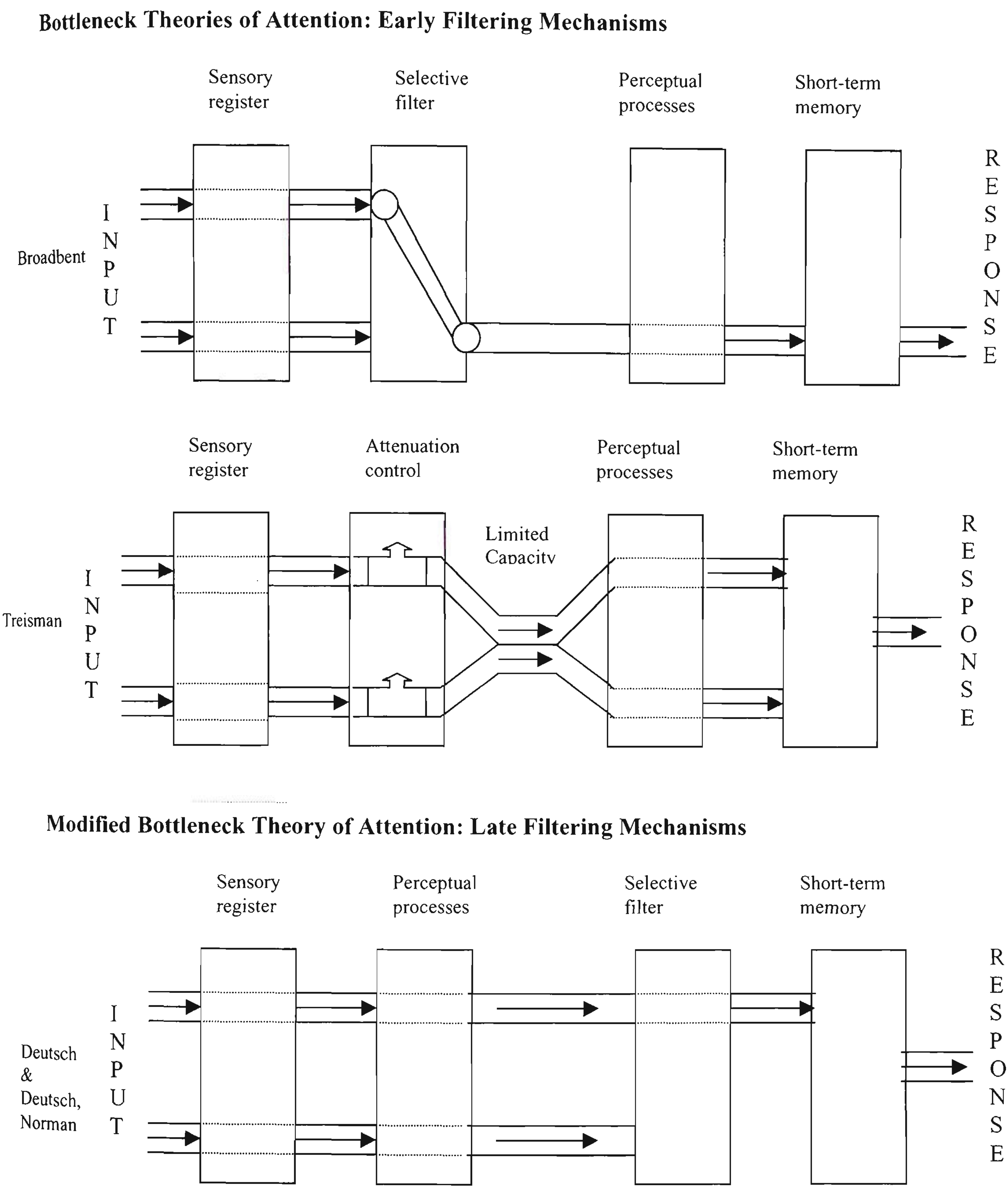

Figure 1. Models of Attention.

From "Conciousness," in R.J. Sternberg's *Psychology: In Search of the Human Mind*, p. 165. Orlando, FL, USA: Harcourt, Inc.

A) Filter Model

This early theory of selective attention was proposed by Donald Broadbent (1958) (Figure 1). A basic assumption of this theory is that sensory information enters the system until a "bottleneck" is reached at which instance the individual chooses to process a message on the basis of some physical characteristics such as the ear or the pitch of the stimulus. At the same time, Broadbent believed that the individual "filters" out the other information. Broadbent's theory was classified as a theory of selective attention, early selection in particular, because the theory concluded that the nervous system acted as a selective filter or switch, which protected the information processing system from overload and passed on only a small, selected portion of the input leaving all the other information blocked (Styles, 1997). Thus only information that passes through the limited capacity channel becomes conscious and is transferred to the individual's long-term knowledge.

In relation to the division of attention, Broadbent (1958) explained that when attention needs to be divided, for example, between two ears simultaneously, the filter is able to switch rapidly between channels on the basis of spatial location or physical characteristics of information in the sensory buffer. He argues that continuous parallel processing between two tasks is not possible because those tasks can proceed only momentarily without attention, thus necessitating rapid switching of attention between them (Styles, 1997). However, this notion, especially the latter one of rapid switching, was seriously challenged by subsequent experiments on divided attention that demonstrated the extended capacity of altering attention between two or more tasks (e.g., Hirst, Spelke, Reaves, Caharack, & Neisser, 1980; Spelke et al., 1976).

B) Attenuation Theory

In 1964, Treisman proposed the attenuation theory (which was also an early selection theory). She suggested that when two messages are presented simultaneously to both ears, certain messages would be weakened but not completely filtered out on the basis of their physical properties. Treisman suggested that semantic selection criteria could apply to all messages, irrespective of whether they were attenuated or not. Treisman thus concluded that features of the message to the unattended ear were not blocked out but that they were "attenuated." She also provided an account of the stage at which selection is made. According to Treisman's results, features of the incoming messages are analyzed successively by the central nervous system, starting with the general physical characteristics and then proceeding to the identification of words and meaning. This early selection model was not totally accepted, as there were still some attributes of the message to the unattended ear that remain explained. Treisman and Gelade (1980) later modified the earlier theory and presented the Feature Integration Theory, which will be discussed later in this chapter.

C) Theory of Late Selection

Deutsch and Deutsch (1963) postulated a theory of late-selection based on neurophysiological evidence they gathered (see Figure 1). They were concerned with identifying how the most important of a group of signals is selected. According to Deutsch and Deutsch's theory, "any given message will only be heeded if the horizontal line (Y) representing the degree of general arousal meets or crosses with the vertical line, the height of which represents the "importance" of the message" (p. 84). They therefore asserted that whether a signal would be attended to depends on both the level of general arousal and on the importance of the message. They also proposed that the information system compares each incoming signal as it arrives, and pushes it up to a "level" that reflects its own "height" or importance. As a result, any other signal that is of less importance would be thrust below this level. However, if the processing of the most important signal ceases, then the level will fall to that of the next most important signal. Thus, after taking into account the individual's arousal level and the importance of the incoming signal, the most important message will be selected, not at an early stage, but after full processing – hence, this theory is considered as a late-selection theory.

D) Automatic and Controlled Processing Theory

Schneider and Shiffrin (1977) proposed a clear distinction between two levels of processing relevant to attention. According to their theory, automatic processing and controlled processing can explain the nature of attention with regard to task performance. Their research (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977) demonstrated that automatic processing is responsible for performing easy tasks, which comprise of highly familiar items and that controlled processing is focussed on performing difficult tasks involving unfamiliar items. Furthermore, automatic processing is parallel, that is, an individual can handle two or more items at the same time (cf, Broadbent, 1958, postulates that parallel processing is not possible); whereas, controlled processing is serial, indicating that only a single item can be attended to at any given time. Another distinction between the two types of processing was identified as the property of controlled processing to be subject to variation through temporary instructions, whereas, automatic processing could not be altered by instructions.

Schneider and Shiffrin's theory also explained the role of the two types of processing on the varieties of attention. The function of automatic processing will be first considered. On a selective-attention task in which people use automatic processing, it would be relatively easy to pick up features of the unattended message and on a divided attention task, in which both tasks require automatic processing, it would be comparatively easy to perform both tasks simultaneously (Matlin, 1998). Shiffrin and Schneider's (1977) theory also explained the relationship between practice and automatic processing, which suggests that tasks that have been extensively practiced will be more prone to automatic processing.

The nature of controlled processing on a selective-attention task can explain the fact that individuals notice few features of the unattended message; and on a divided-attention task, individuals will face difficulty in performing two tasks simultaneously if using controlled processing (Matlin, 1998). Thus, tasks that have not been extensively practiced will usually involve controlled processing.

The automatic and controlled processing theory (Shiffrin & Schneider, 1977; Schneider & Shiffrin, 1977) has been widely influential and has played an important role in construing the effects of practice on performance and clarifying differences in performances on dual-attention tasks.

E) Feature Integration Theory

This theory of visual attention has been in a state of constant evolution. It was originally proposed by Treisman and Gelade (1980) and has since been modified by Treisman (1988, 1993). The basic premise of the theory is that individuals sometimes process a scene automatically, with all parts of the scene processed at the same time; on other occasions, individuals use focused attention, with each item processed one at a time. Initially, Treisman and Gelade (1980) distinguished between preattentive processing and focused attention; preattentive processing involves the automatic registration of features using parallel processing whereas, focused attention involves serial processing which is required when objects are more complex. Treisman (1993) defines functional features as "properties for which we have evolved or acquired separate sets of detectors responding in parallel across the visual scene" (p. 7). Furthermore, she elaborates on features on a behavioural basis as attributes which allow "pop-out", mediate texture segregation, and may be recombined as illusory conjunctions.

Treisman (1993) extended her earlier theory by accommodating divided attention rather than preattentive processing, along with focused attention. Thus according to the recent development of the theory, divided attention is responsible for the functions previously performed by preattentive processing. Furthermore, divided attention and focused attention can be described as forming a continuum; hence, an individual will use a type of attention that is present between the two extremes of divided and focused attention. It appears that as research progresses, clear-cut distinctions between systems are reduced and the supposition that there is more interaction and integration between systems and processes is discovered.

F) Theory of Visual Attention

Two recent theories of visual attention that were based on mathematical modelling are the Theory of Visual Attention (TVA) (Bundesen, 1990) and the CODE Theory of Visual Attention (CTVA) (Logan, 1996). Bundesen formulated the TVA as a model of visual recognition and attentional selection and aimed to explain the process by which people choose a stimulus among several inputs presented to them.

He achieved this by modelling two attentional mechanisms, filtering and pigeon-holing, which were initially proposed by Broadbent (1971). Bundesen defined filtering as the selection of elements from the visual field, and pigeon-holing as the selection of categories. The model elucidates the idea that items are composed of features and assumes two levels of representation: (a) a perceptual level that consists of features of display items, and (b) a conceptual level that consists of categorizations of display items and display features.

Apart from proposing other concepts, Bundesen's (1990) theory could predict reaction time and accuracy. Logan (1996) further extended Bundesen's theory and incorporated these characteristics into his CTVA theory. Bundesen argued that reaction time and accuracy depend on three parameters: the strength of the sensory evidence, the perceptual bias, and, pertinence. He strengthened his arguments by providing firm mathematical formulations. Bundesen's (1990) theory had great relevance in advancing later mathematical models of attention and hence was substantially adopted (along with the earlier CODE theory proposed by van Oeffelen & Vos, 1982) by Logan's (1996) CTVA.

G) CODE (Contour Detector) Theory of Visual Attention

In 1996, Logan integrated the space-based and object-based theories of attention to construct the CODE Theory of Visual Attention (CTVA). The theory is one that is complex but integral in elucidating the unison between object and spaced based theories. This theory was put forth by combining van Oeffelen and Vos's (1982) CODE (Contour Detector) theory of perceptual grouping by proximity with Bundesen's (1990) theory of visual attention. The CTVA has adopted a computational approach to proposing a theory of visual spatial attention and characterises attention "in terms of representations and the processes that operate on them" (Logan, 1996, p. 603). Logan explains that the theory differs from other approaches to attention as it is interested in the representation of space and objects.

In contrast to the TVA, which treats items as discrete units, the CTVA considers items as spatial distributions and attaches sensory evidence and attentional weights to parts of those distributions (Logan, 1996). Some of the other significant features of the CTVA are that the theory can process displays in parallel or in series (whereas TVA processes only in parallel). Logan (1996) emphasizes that processing between perceptual groups can be serial or parallel, depending on the task and the situation, and continues to accent the fact that CTVA is midway between theories like TVA that process all items at once and theories like Treisman's feature-integration theory (Treisman & Gelade, 1980) that process items one at a time. Logan has clearly outlined the manner in which selection occurs within the focus of attention. He indicates that the individual "controls a bias parameter that makes a particular categorization more likely and a priority parameter that makes relevant objects more likely to be selected" (p. 635). In relation to responses by the individual, Logan suggests that the person controls the response criteria that determine the number of counts required to categorize a particular object. An important contribution of the CTVA was that it provided a quantitative account to visual spatial attention, whereas previous theories were only qualitative assessments.

It can be argued that the modelling of attention is an ongoing process in which one witnesses the emergence of a variety of theories and constant modifications of existing ones. Indeed, attention is such an intriguing and important concept, as initially acknowledged, that people have never grown out of interest in studying it. Although theories of attention were established by students of attention (e.g., Treisman) over four decades ago, the topic of 'attention' has been a central topic to understanding human cognition. It is the belief of the author that attention will remain be a core topic of research in cognitive psychology for a conceivable amount of time in the future. To summarise, as Gopher (1990) aptly states, the study of attention comprises "all manifestations of behavior that involve the active influence of the human mind (which in contemporary terminology is often termed the human processing and response system) on the perception and transformation of stimuli from the outside world, and on the preparation and conduct of response" (p. 25).

DIVIDED ATTENTION

The ability to attend and process information from more than one source simultaneously in known as divided attention (Matlin, 1998; Stuart-Hamilton, 1995). It is critical to understand the processing capacity of the human cognitive system as individuals face a variety of situations everyday – some easy, whereas, others that require division of attention, more difficult. A task can become difficult when it is to be carried out in conjunction with other tasks simultaneously. Hence it is important to investigate how several different tasks can be performed concurrently in a successful manner and what strategies can be adopted to achieve successful division of attention.

Studies on divided attention investigate the processing and response limitations of the human system. In such studies, participants are usually presented with two or more sets of stimuli at the same time and their ability to process and respond to all of the stimuli is examined. The dual-task paradigm is a useful research tool as it "compensates for the inability to decompose, identify, and provide clear descriptions and measures of the components, processes and demands which comprise a single experimental task" (Gopher, 1990). In other words, it can be applied to a variety of investigations on individual differences in attention capabilities across a range of topics such as attention limitations, workload, coordination of activities, and coping skills on demanding tasks (Gopher, 1990). It also "provides a vehicle for investigating changes in processing capacity during the learning of a complex skill" (Crosby & Parkinson, 1979, p. 1302) when the interference between primary and secondary tasks is a reflection of competition for central resources and the effect of learning is to decrease the processing resources required by the primary task.

Previous research has shown that successful combinations of tasks involve presentation of information regarding the two tasks to separate modalities (e.g., vision and hearing) (Stoffregen & Becklen, 1989). On the other hand, decrements in performance have been noted when tasks have been presented to a single modality (Allport, Antonis, & Reynolds, 1972; Neisser & Becklen, 1975; Stoffregen & Becklen, 1989). Therefore, it is necessary to examine how the presentation mode of tasks will impact on performance. In order to understand this, some of the theories concerning the nature of dual-task performance are discussed.

Theories of Divided Attention

A) Theory of Attention and Effort

A well-known theory of divided attention is put forward by Kahneman (1973). According to Kahneman, attention is a limited resource that can be made flexible as the individual changes his or her allocation policy from moment to moment. Thus attention can be directed to a single task or divided between several activities. In Kahneman's theory, attention is related to effort: the amount of effort an individual is able to apply towards a task is relevant to the performance on the task. This effort is associated with the arousal level of the individual, hence, as arousal increases, so does the attentional capacity, and vice versa.

B) Resource Allocation theory

Researchers have theorized the ability to divide attention to be based on the amount of resources available rather than effort (Norman & Bobrow, 1975; Wickens, 1984). According to this theory, when two tasks are combined, resources must be allocated between both tasks and depending on the priority of the tasks, more or less resources can be allocated to either of the tasks (Wickens, 1984). Norman and Bobrow (1975) believed that there could be a variety of resources including "processing effort, the various forms of memory capacity and communications channels" (p. 45). One limitation of this theory is the difficulty of measuring the resource demands made by the tasks and whether these resources are from the same or different pools (Styles, 1997).

To investigate the number of resources available to perform dual tasks, McLeod (1977, 1978) conducted an experiment in which participants were required to perform a letter-matching and a tone detection task. Initially a warning signal was followed by the presentation of a letter and after half a second, another letter was presented. The participant was required to judge whether or not the letters were the same and respond by pressing a key. While participants were performing the letter-matching task, they were also monitoring for the presentation of an auditory tone. Until this stage, Mcleod replicated the Posner and Boies (1971) experiment. However, in contrast to Posner and Boies' (1971) experiment where participants were required to respond to the auditory tone by pressing a key, Mcleod asked his participants to say "bip" on hearing the tone.

While Posner and Boies (1971) revealed a slower reaction time when the auditory tone was presented simultaneously with either of the letters, Mcleod (1977, 1978) found no interference between the letter-matching task and tone detection. Therefore, while Posner and Boies' results could be taken as evidence for a general limit on attentional processing, Mcleod's findings demonstrates that there is no attentional limit on the participant's ability to perform two tasks concurrently. The results from the two experiments suggest that humans are limited in making two similar responses (pressing keys) to two different tasks, whereas there is less interference (and hence, a greater capacity to perform concurrent tasks) when the responses are different (pressing a key for the letter-matching task and saying "bip" upon detecting the tone) to two different tasks.

C) Automatic and Controlled Processing Theory (an extension)

According to the Automatic and Controlled Processing theory (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977) previously discussed under the theories of attention, two or more tasks can be performed more efficiently when the attention process has become automatic and this automaticity can occur after sufficient practice. One drawback of this type of processing is that performance may be prone to more errors. On the other hand, if quick response times were necessary on two concurrent tasks, controlled processing would not be effective. Controlled processing occurs as a result of insufficient practice with the two tasks. However, if flexibility is required in performing the two tasks, controlled processing can be utilized (Posner & Snyder, 1975). Upon conducting an extensive review of studies in the field of attention, Cowan (1997) attributes much of the attentional processing to be automatic.

Automaticity and Attention

J. R. Anderson (2000) indicates that the general impact of practice is to reduce the central cognitive component. When the individual has practiced the central cognitive component to an extent that the task requires little or no thought, performing the task is said to be automatic. Similarly, the automatic processing model of attention (e.g., LaBerge, 1975) implies that highly practiced activities become automatic thereby requiring less attention than new or slightly practiced activities. For example, while driving a car, an individual may simultaneously look at a map, eat a burger, put on sunglasses, talk to his companion, and so on. In terms of allocating effort, however, more attention is being directed to driving than other activities, even though some attention is given to other activities. This allocation of attention to different tasks takes place as a result of practice.

Shiffrin and Schneider's (1977) results of measuring performance on same or different category experiments after practice also demonstrate that processes can become automatic with enough practice. It is indicated that when they do, devoting attention to them is no longer necessary and performance is no longer affected by the number of processes being performed simultaneously (but by the amount of practice received in the past). Shiffrin and Schneider (1977) further reiterate that automaticity could be the key to attending to processing several bits of information simultaneously, without greatly affecting encoding of the information and performance on the tasks. Similarly, Posner and Snyder (1975) have suggested that an activity or a mental process might be called 'automatic' if it does not interfere with a concurrent attentive activity.

Contrary to this view, other researchers believe that automatic processing has the properties of well-practiced memory retrieval. They construe automaticity as a memory phenomenon, "governed by the theoretical and empirical principles that govern memory" (Logan, 1992, p. 321). For example, it has been asserted that non-automatic performance is based on a general "alogrithm" for solving difficulties of a task, whereas automatic performance is based on a single-step, direct-access retrieval of previously created solutions from memory (J. R. Anderson, 1982; Logan, 1988, 1992; Newell & Rosenbloom, 1981; Schneider, 1985). From this perspective, automatic processing involves attention. Logan (1992) further elaborates that whereas novices attend to various steps of a task to produce a solution, highly practiced individuals attend to the solutions that memory provides. Thus, "automatic processing is intricately dependent on attention, not independent of it" (Logan, 1992, p. 321).

Effect of Practice on Dual-attention Tasks

"Humans have limited knowledge on the efficiency of their efforts. They can be trained to develop better attention allocation policies, and strategies of coping with concurrent complex demands" (Gopher, 1990, p. 27).

It has been the purpose of many decades of research to find means to extend the human processing capacity to enhance dual-task efficiency through practice. Several early and contemporary theories indicate that to understand simultaneous messages, some sacrifice must be made. When attention is divided, individuals fail to perceive stimuli accurately (e.g., Broadbent, 1958; Mitsuda, 1968; Reinitz et al., 1994). However, practice plays a key role in the ability of an individual to divide his or her attention between two or more tasks (Allport et al., 1972; Hirst, 1986; Hirst et al., 1980; Spelke et al., 1976; Stoffregen & Becklen, 1989). Allport (1986) too confirms that humans do not have a built-in, fixed limit to the number of tasks they can perform simultaneously.

Indeed, the research literature on divided attention implicitly recognizes the effects of practice on attentional strategies. It has been shown that extended practice can dramatically improve performance in two-channel monitoring (Underwood, 1974). Brown and Poulton (1961) showed that as people become better drivers, they could perform increasingly more complex mental calculations while they drive. These findings confirm the postulate that humans can learn to perform two independent and demanding tasks simultaneously (Hirst et al., 1980).

With extensive practice, performance on the tasks can become "automatic." Logan (1988) argued that practice in a consistent environment is essential for processing to become automatic because consistency ensures that the retrieved *instances* (representations) will be useful. He indicated that practice is important because it enhances the amount of information that is retrieved and the speed of retrieval.

Spelke et al. (1976) examined the effects of extended practice on peoples' ability to develop skills in divided attention. They investigated reading speed, reading comprehension, dictation rate and recognition memory for the dictated words in a study involving reading of short stories while simultaneously writing unrelated dictated words. The participants received 20 weeks of practice. At the beginning, the participants faced difficulty in combining reading and writing. They could not detect the semantic relations among the dictated words either. However, as practice continued, they became more successful in combining the reading and writing task, comprehending the story, and determining the semantically related words.

Interestingly, the authors found that memory for the dictated words was poor, with either of the participants not recalling more than two words from any list, and this suggests that attention is necessary for remembering (Styles, 1997). Indeed, Moray (1959) also discovered that words presented to the unattended channel in a dichotic listening task were not recalled even after many presentations.

In Spelke et al.'s (1976) experiment, the two participants were finally able to categorise the dictated words while simultaneously maintaining the reading speed and comprehension of the story. This study shows that through extensive practice, individuals can substantially increase their ability to perform two complex activities simultaneously (Spelke et al., 1976). Thus the participants "achieved a true division of attention" (p. 229). The study also challenges the notion that there are fixed limits to attentional capacity.

Spelke et al. (1976) attributed the achievements of their two participants to three possible explanations: first, it could be possible that the participants showed improvements by exerting extra effort to increase the amount of resources available to perform the tasks of reading and writing (in consonance with Kahenman's 1973 theory). However, this line of reasoning seemed to be the least plausible as the participants were enthusiastic about performing the tasks to the best they could from the start; also, as practice increased, the participants expended less effort rather than more. Second, it was suggested that the participants, rather than performing both tasks at once, attended to them in rapid alternation (in accord with Broadbent's 1954 theory); i.e., they may have learned to "time share" their capacity. Third, it was argued that the participants may not have used their central processing capacity, rather, they may have performed the tasks "automatically" without attending to them.

Hirst et al. (1980) investigated the second and third lines of reasoning in a study similar to Spelke et al. (1976). This has also been an influential study on divided attention. The authors hypothesised division of attention could occur without alternation or automaticity. Their first experiment replicated Spelke et al's. (1976) finding that with sufficient practice, people can learn to read at an adequate speed level, while comprehending the story, as well as copying dictated words. Thus they investigated: 1) if participants could achieve the skill previously acquired by the two participants in Spelke et al.'s (1976) study, and, 2) the degree of transfer that could be achieved when participants trained in one type of reading material (for e.g., short stories) performed on a different set of reading material (such as encyclopaedia articles).

Hirst et al. (1980) found that with sufficient practice, participants could learn to read and write with no loss of speed or comprehension. The experiment also indicated that the skill acquired by most participants from one genre of reading material did transfer to another genre. In addition, the findings revealed that the redundancy of the reading material was not used to accomplish the task of writing, which is similar to Stoffregen and Becklen's (1989) finding wherein participants were not evidenced to take advantage of redundant material to accomplish a task.

Experiment 2 of the Hirst et al. (1980) study investigated the automaticity hypothesis by training participants to complete sentences while reading. Hirst et al. found that with practice, the participants were able to understand the meaning of the sentences, make fewer copying errors with real sentences than with a list of random words, recall real sentences better than random words, and integrate information from successive sentences. In view of this evidence, the authors concluded that the ability to divide attention is constrained primarily by the individual's level of skill, which can be developed and enhanced through sufficient practice and that the participants in their study did not perform the tasks in an automatic manner.

Neisser (1976) confirmed that practice can lead to strategic improvement in dual attentio. Taken together, these findings highlight the role of practice in performance on dual-attention tasks. Although Hirst et al. (1980) and Spelke et al. (1976) showed the effects of extended practice on divided attention skills, Stoffregen and Becklen (1989) demonstrated that novel, continuous, dynamically structured tasks (such as responding to a basketball game shown on video tape and a vocalizing human face) can be successfully combined after only two days of practice.

In summary, the discussions on divided attention emphasise that human performance can be understood through careful investigations utilizing the dual-task method.

Necessity of dual-attention skills

People attend to several tasks simultaneously while watching the television and engaging in a conversation with someone, while cooking two dishes at one time, driving a vehicle, or performing the job of an air traffic controller. The consequences of divided attention on task performance can even be life threatening. For example, in Yugoslavia, in 1976, two airplanes collided and all 176 passengers and crew-members were killed. The sole air-traffic controller had been monitoring eleven aircraft simultaneously. In the preceding minutes to the accident, he had transmitted eight messages and received eleven (Barber, 1988). Although humans are extremely competent, they cannot pay attention to everything at the same time (Matlin, 1998). Hence it is essential the individual have the necessary skills to cope with the demanding responsibilities effectively. These skills could be enhanced through developing a better strategy of dividing one's attention proficiently.

Improvement in such skills could aid the provision of informal education for occupations that demand skills in divided attention (Greenfield, DeWinstanley et al., 1994) including instrument flying, military activities, and air traffic control. Crosby and Parkinson (1979) have clarified the importance of divided attention skills in real flight. Gopher, Weil and Bareket (1994) emphatically showed that skills acquired through computer game practice could transfer to flight performance.

Researchers established a high correlation between performance on a flight simulator for aircraft carrier landing and that on the Atari home video game "Air Combat Maneuvering" (Lintern & Kennedy, 1984). One reason for the correlation might be the skill of divided attention, as many flight tasks indeed involve divided attention. Pilots usually have to keep track of a lot of different instruments-for example, a row of six engine dials which is similar to a some types of video games (Greenfield, DeWinstanley et al., 1994).

It can thus be seen that dual-attention skills are vital in everyday activities as well as more complex tasks. Previous research has shown that humans do not have a built-in, fixed limit to the number of tasks they can perform simultaneously (Allport, 1986). It is therefore essential to capitalize on the enormous human capacity to execute complex cognitive functions in order to increase task efficiency.

Neurocognitive Basis of Attention

In the present day, various techniques such as the electroencephalogram (EEG), positron emission tomography (PET), and magnetic resonance imaging (MRI) help understanding the neural mechanisms responsible for different brain activities. Researchers have shown that different brain regions may control different components of attentional processing. For example, Posner and Petersen (1990) proposed that the posterior brain system mediates attention to spatial locations, whereas the anterior system influences attention to cognitive operations. More specifically, Posner and Rothbart (1991) reiterate that the anterior system is active whenever the task required effortful attending on the part of the participant, whereas the posterior system is involved in vigilance tasks.

Mirsky (1996) has outlined the brain systems associated with the functioning of some of the attentional functions including the ability to focus or execute, sustain, and shift. In a healthy brain, different brain regions may be responsible for different functions. However, there may be shared responsibility or substitution in the event of injury to any part of the system (Mirsky, 1996). According to Mirsky (1996), the function of focusing attention is shared by the superior temporal and inferior parietal cortices as well as structures that comprise the corpus striatum. The allocation of attention to the execution of responses is dependent on the performance of the inferior parietal and corpus striatal regions and sustaining attention is the responsibility of rostral midbrain structures (Mirsky, 1996), whereas the capacity to shift attention is supported by the prefrontal cortex including the anterior cingulate gyrus (Mirsky, 1996; Posner & Rothbart, 1991). Research into the neurocognitive basis of attention includes a variety of investigations into different types of attention. For instance, there has been a considerable amount of examination into visual attention (O'Craven, Downing, & Kanwisher, 1999; Usher & Niebur, 1996) and spatial attention (Heilman, Watson, Valenstein, & Damasio, 1983; Mesulam, 1987).

In relation to video game playing and attentional resources, the most convincing argument has come from Koepp et al. (1998) who provided evidence for the release of striatal dopamine during a video game play. Studies have shown that dopamine release may be involved in learning, reinforcement of behaviour, sensorimotor integration, and more importantly, attention (Robbins & Everitt, 1992; Schultz, Apicella, & Ljungberg, 1993). Interestingly, Koepp et al. (1998) found for the first time a behavioural condition, i.e., video game playing under which dopamine is released in humans. They induced C-labelled raclopride (RAC) (which can detect changes in levels of extracellular dopamine) to their participants and used PET scans to assess the striatal dopamine release during video game play as well as under a control condition. In their study of the "cognitive neurochemistry of behaviour," they measured the binding of C-RAC to dopamine receptors in the ventral and dorsal striata and found a reduction in the binding of RAC to dopamine receptors during video game play compared to baseline levels of binding. Related research by Richardson and Gratton (1996) has found that a one per cent decrease in C-RAC binding reflects at least an eight per cent increase in extracellular endogenous dopamine levels. Thus the 13 per cent reduction in C-RAC binding potential that Koepp et al. (1998) found suggests a two-fold increase in levels of extracellular dopamine.

Further, Koepp et al. (1998) demonstrated the prolonged alterations in dopamine levels even after 50 minutes after the game had ended. This gives rise to the assumption that a heightened state of attention reached during video game play continues long after the individual finished playing the game, thereby, altering the release of dopamine. The study also found a significant correlation between performance on the video game and reduced C-RAC binding potential in all striatal regions. The researchers interpret changes in the ventral striatal C-RAC binding to be related to the affective constituents of the task, and dorsal striatal dopamine release to sensorimotor coordination and response selection.

It is thus possible that there are several brain regions involved in the mechanism of attention and other external media (such as video games) that can accelerate the involvement of brain transmitters (such as dopamine). The latter finding has important implications for ways in which endocrinal brain activities can be increased by behavioural modes, especially in individuals who lack the capacity to attend due to neurological disorders. There is some evidence to show that video games could be applied to treat children afflicted by Attention Deficit Hyperactivity Disorder (Braukus, Henry, & Gardner, 2000).

Individual Differences in Divided Attention

Differences in individual ability to allocate attention to more than one task can arise as a result of practice (Brown & Poulton, 1961; Hirst, 1986; Hirst et al., 1980; Spelke et al., 1976; Stoffregen & Becklen, 1989; Underwood, 1974). Large amounts of practice improves performance and leads to people becoming 'experts' (Frensch & R.J. Sternberg, 1991) compared to novices who have not received as much practice. Experts have been shown to perform better on divided attention tasks compared to novices (Greenfield, Brannon et al., 1994).

Individual differences in skills of divided attention could also occur through aging (N.D. Anderson, Craik, & Naveh-Benjamin, 1998; N.D. Anderson, 1999; Hartley & Little, 1999, Park, Smith, Dudley, & Lafronza, 1989). Age has been to be a causal factor for decline in performance on a dual-attention task in a number of studies (e.g., N.D. Anderson, et al., 1998; N.D. Anderson, 1999), however, others (e.g., Hartley & Little) have demonstrated that there was no evidence for a specific impairment in the ability of older adults to manage simultaneous tasks. Hartley and Little (1999) explain the absence of an interaction between younger and older adults on the divided attention tasks either due to the lack of pressure to respond quickly, or due to the responses to the two tasks in different modalities. The extant literature did not reveal any sex differences in the ability to divide attention. Overall, it can be seen that the ability to divide attention is primarily constrained by the individual's level of skill, which can be enhanced by adopting strategies to develop the skill.

Measurement of Attention

The study of attention is wide-ranging in terms of the measures and constructs used to assess the process. The main experimental paradigms can be classified into the following four dimensions.

A) Time

Time is a relevant factor that distinguishes between studies concentrating on the short term, immediate effects of attention on performance, and investigations in long duration tasks of sustained attention (Gopher, 1990). Time has also been used as a resource in examining the relations between the time available for encoding and retrieval processes and memory performance (Craik, Govoni, Naveh-Benjamin, & N.D. Anderson, 1996); it has been extensively considered in studies in divided attention as well as those measuring individuals' ability to maintain vigilance and alertness over long periods (related to sustained attention).

B) Type of Task

Kahneman and Triesman (1984) postulate that experimental tasks can be generally classified into the filter paradigm and the selective set paradigm. This notion has been extended by studies measuring performance on two concurrent tasks to include the divided attention paradigm. In the filter paradigm, the participant is exposed simultaneously to relevant and irrelevant stimuli such as the shadowing task used by Cherry (1953) and Moray (1959) where participants are required to attend to a string of words presented to one ear while ignoring the contents presented to the other ear. The main measure of performance in such tasks is accuracy (Gopher, 1990).

In the selective set paradigm, the participant is prepared for particular stimuli and is required to perform a speeded response (or reaction time) task to indicate the detection or recognition of those particular stimuli (Gopher, 1990). On the other hand, individuals performing a divided attention task are required to simultaneously attend to two (or more) *concurrent* tasks and respond to both in an appropriate manner. One may be referred to as the primary task and the other, the secondary task (Crosby & Parkinson, 1979).

C) Attention assignment

It has been elucidated that the difference in executing tasks is whether the task is performed under focused or divided attention instructions. Tasks of focused or selective attention are used to study the resistance to competing stimuli; whereas, divided attention tasks are used to measure the limits of performance and the extent to which different concurrent tasks can be performed or combined without loss (Gopher, 1990).

Attention assignment in divided attention tasks can be further classified based on the instructions provided regarding the emphasis on the two tasks. For example, Craik et al. (Experiment 2, 1996) conducted a dual-attention experiment involving a memory task and a reaction time task under three emphasis conditions: a greater emphasis on memory performance, or, the reaction time task, or equal emphasis on both tasks.

In a similar manner, Crosby and Parkinson (1979) have described two versions of the dual-task paradigm – 'loading' and 'subsidiary.' Originally developed by Knowles (1963) and Rolfe (1971), the terms refer to the function of the secondary task. In the loading version, the instructions emphasize that both primary and secondary tasks must be done at the same time, and the main measure is the level of performance achieved on the primary task relative to when it is performed alone (Crosby & Parkinson, 1979). On the other hand, in the subsidiary version, the main emphasis is on the primary task while performing the secondary task to the best level possible without interference. The main dependent variable in this scenario is the level of performance attained on the secondary task. The difference in the experimental manipulations by Craik et al. (1996) and Crosby and Parkinson (1979) lies in the assessment of performance of the primary and secondary tasks, or either only the primary task or only the secondary task, respectively.

D) Stimulus and response characteristics

Gopher (1990) has outlined the large variations in the selection of stimuli and responses, and in the choice of variables along with which they are manipulated in studies of attention. The tasks may vary in the modality of presentation, physical properties, semantic attributes, and type of responses (Gopher, 1990).

Thus it can be seen that attention can be measured in different ways depending on the primary aim of the investigation. Manipulations can be made by the experimenter by way of instruction, presentation of stimuli, or through the measurement of performance.

Video Games and Divided Attention Skills

Although some of the issues in this section have been discussed briefly in the chapter on 'video games,' it is important to reiterate and elaborate them further.

Research has consistently shown that efficient control of attention is a skill that can be trained and improved. One medium that could assist in the development of dual attention skills is the popular video game. Video games are interactive and have been revealed to be a cultural artifact (Greenfield, 1994). Greenfield (1984) and Schribner and Cole (1981) indicate that cognitive processes most often depend on interacting with either people or cultural artifacts. In fact, the games have been described as "cultural artifacts that require and develop a particular set of cognitive skills; they are a cultural instrument of cognitive socialization" (Greenfield, 1994, p. 5). It is thus important to measure the extent to which video game practice develops cognitive skills such as divided attention.

Braun and Giroux (1989) have explained that when playing video games, players are required to constantly and simultaneously process multimodal perceptual information and respond to it with coordinated motor sequences on the basis of cognitive modelling, executive planning, and evaluation of ongoing feedback. It has seen also been noted that video game players are constantly monitoring several targets appearing simultaneously at several locations on the video screen (Gagnon, 1985; Greenfield, 1984), as well as controlling the different buttons on the controller *and* moving the joystick in the appropriate directions. Apart from these actions, the players are also able to converse logically. In addition to the above findings, there is anecdotal evidence from parents who provided instructions to their child who was playing video games and presumed that their child was unaware of the instructions given. However, to the parents' bewilderment, the child repeated all the instructions upon game completion. Such reports suggest that video games are surreptitiously allowing players to develop strategies to attend to several tasks simultaneously.

In light of the above observations, Greenfield, DeWinstanley et al. (1994) investigated the effects of video game expertise on divided visual attention. They measured divided attention by using response time to targets of varying probabilities at two locations on a computer screen. In one condition, the target appeared 10 per cent of the time in one location (low probability target), 80 per cent of the time in the other location (high probability position), and 10 per cent of the time in both locations. In the second condition, the target appeared 45 per cent of the time in each of the two positions and 10 per cent of the time in both positions.

The results shown in Figure 2 were interpreted in terms of a cost-benefit analysis, established that both experts and novices displayed an attentional benefit at the high probability position. However, while the expert video game players did not show an attentional cost (in terms of a slower reaction time) at the low probability (10%) position, the mean reaction time for novices was longer at the 10 per cent location compared to the 45 per cent location. These results suggest that skilled video game players had better skills for monitoring two locations on a visual attention task.

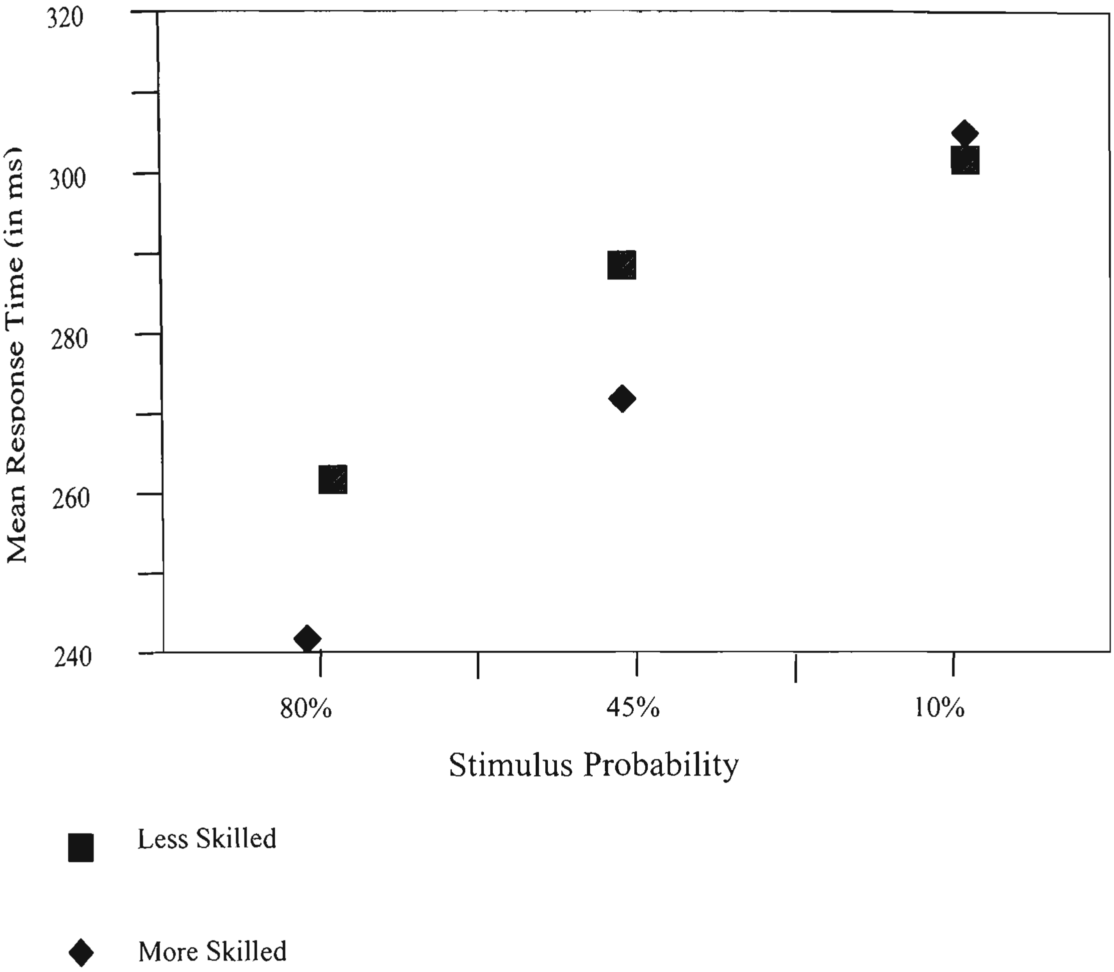

Figure 2. Relationship between video game expertise and strategies for dividing attention.

From Action Video Games and Informal Education: Effects on Strategies for Dividing Visual Attention," by Greenfield, DeWinstanley et al., 1994, *Journal of Applied Developmental Psychology, 15*, p. 117.

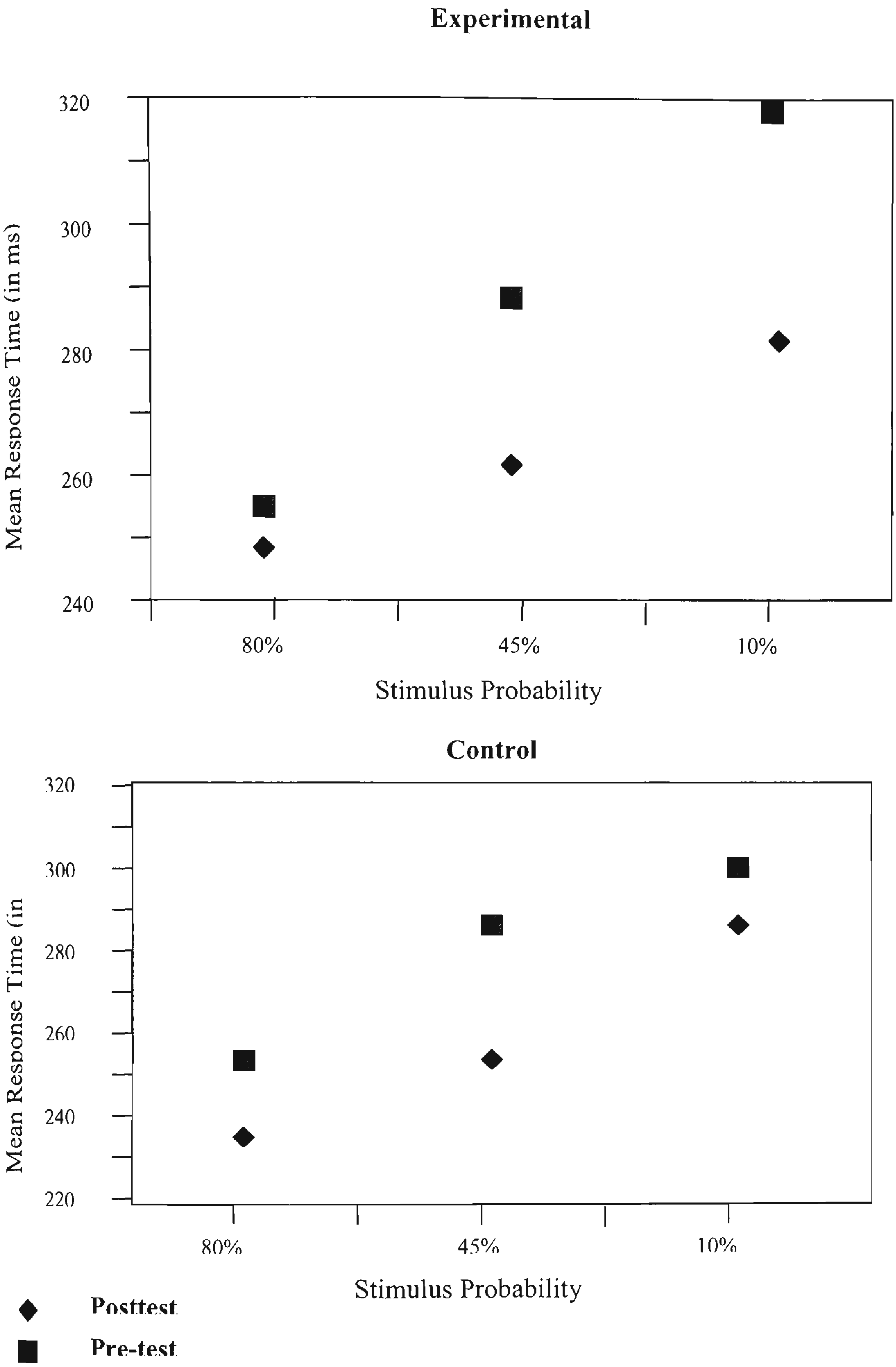

Figure 3. Effect of video game practice on cost-benefit patterns in the allocation of visual attention.

From "Action Video Games and Informal Education: Strategies for Dividing Visual Attention," by P. M. Greenfield, P. DeWinstanley et al, 1994, *Journal of Applied Developmental Psychology, 15,* p. 118.

Experiment 2 of Greenfield, DeWinstanley et al.'s (1994) study investigated the strategic deployment of divided spatial attention as a function of video game expertise. Participants were categorised into groups of expert and novice video game players and randomly assigned to either the experimental or control group. The experimental group received five hours of video game practice on a game called 'Robotron' while the control group did not receive this practice. The measure of attention was similar to that used in Experiment 1. The findings suggest that experimental video game practice could alter the strategies of attentional deployment.

The authors summarised "experimental video game treatment moved players from a cost-benefit pattern of attention that, at pretest, was relatively more like that of novices in Experiment 1 to a pattern that, at posttest, was relatively more like that of experts in Experiment 1" (p. 117) (see Figure 3). They also explained that the control group drifted from a cost-benefit pattern that, at pretest, was similar to that of the experts in Experiment 1 towards one that, at posttest seemed increasingly like that of the Experiment 1 novices (see Figure 3). In attempting to explain how individuals can sometimes perform a visual task very efficiently under divided attention conditions, it has been proposed that the visual system manages to extract enough information during this challenging situation to guide further attention (Wolfe, 1992).

Results from both Experiments 1 and 2 of Greenfield, DeWinstanley et al.'s (1994) study demonstrate that skilled video game players performed better while monitoring two locations on a visual screen and that experimental video game practice could alter strategies of attentional deployment so that reaction time for a low-probability target was reduced. Thus they provided evidence that "video games are a tool of informal education for the development of strategies of divided attention" (p. 121).

In another study by Clark, Lanphear, and Riddick (1987), the effects of practice in video game playing was shown clearly when participants improved their performance on an attention task as a result of playing a minimum of 14 hours of 'Pac-Man' and 'Donkey Kong' over a period of seven weeks. The largest effect of this practice appeared in the strategic reaction-time task in which the participants' right hand had to respond to a stimulus on the left while the left hand had to respond to a stimulus on the right. The above results are similar to Greenfield, DeWinstanley et al.'s (1994a) finding of a strategic change in the pattern of attention deployment as a result of experimental video game practice.

In summary, this chapter has elucidated the theories of attention and divided attention and focused on the influence of practice on improving divided attention skills. It has also illustrated the possibilities of improving these skills through video game playing.

MEMORY

"Memory reaches its evolutionary culmination in human beings" (Tulving & Craik, 2000).

MODELS OF MEMORY

Human memory has been rigorously studied over the past five decades or so, although Ebbinghaus started the initial work in 1885. Various models have since been constructed and several theories put forth concerning the different memory processes. The most dominant models have weathered the rigours of modern experimental research. These include the distinction of memory systems into sensory, short-term, and long-term memory capacities (Atkinson & Shiffrin, 1968), the levels of processing approach (Craik & Lockhart, 1972); the systems theory of memory (Tulving, 1972, 1983); and, the working memory model (Baddeley & Hitch, 1974) apart from others. These memory models will be briefly described.

A) Modal Memory Model (Atkinson & Shiffrin, 1968)

According to the dominant information processing approach of memory, information is processed in a series of steps (S. Sternberg, 1966). Atkinson and Shiffrin (1968) made the first comprehensive endeavour to divide the human memory into different systems (see Figure 4). This approach has also come to be known as the "Modal Memory Model" (Pashler & Carrier, 1996) because it is both typical and influential. According to Atkinson and Shiffrin (1968), the memory system can be distinguished into three capacities: sensory memory, short-term memory (STM), and long-term memory (LTM). Although some researchers believe that these categorisations are not valid, there is a lack of conclusive evidence to disprove these distinctions (Pashler & Carrier, 1996) and reference is made to these systems in recent publications elucidating the memory systems (e.g., Pashler & Carrier, 1996; Tulving & Craik, 2000). Atkinson and Shiffrin (1971) described information flow in the memory system begins with the processing of environmental inputs through the sensory system, which then enter the short-term store (STS). This information then enters the long-term store (LTS) where it could activate associated information, which could then enter the STS (Atkinson & Shiffrin, 1971).

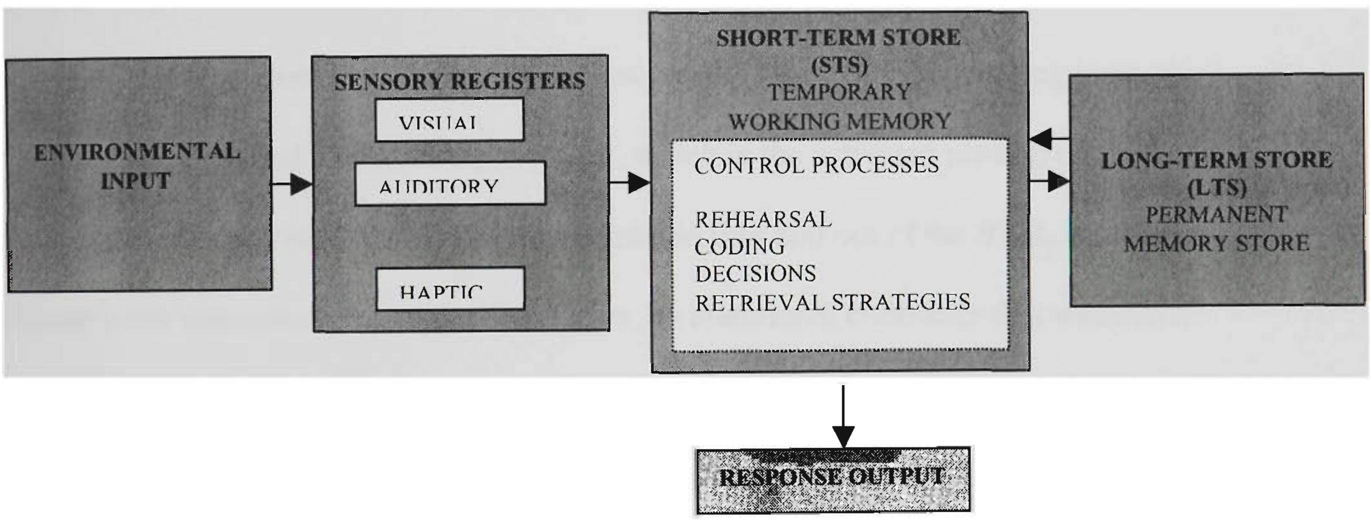

Figure 4. Richard Atkinson and Richard Shiffrin's model of memory.
From "*Psychology: In search of the human mind*" (3rd ed.), by R.J. Sternberg, 2001, p. 232. Orlando, FL: Harcourt, Inc.

The theory of short-term memory (STM) proposed that attended information first reached the intermediate STM where it had to be rehearsed prior to being held permanently in the long-term memory (LTM); it also postulated that the STM has a limited capacity (around seven items) to hold information (J.R. Anderson, 2000). Counter-theories were proposed with regard to the division of memory into the three systems and the procedure of learning new information and storing it in the LTM only via the STM. Some of the contrasting evidence came from a study (Shallice & Warrington, 1970) on a brain-damaged patient who had been shown to have very poor STM, yet the person's LTM ability was unimpaired.

B) Working Memory Model (Baddeley & Hitch, 1974)

The STM was also argued not to be a single unitary system, but rather an amalgam of several temporary memory systems working together. Baddeley and Hitch (1974) conducted a series of experiments on the role of memory in reasoning, language comprehension, and learning, and proposed a theory of the working memory system. They asserted that working memory, which is the activated portion of the LTM that moves activated elements of information into and out of the STM, consists of three main elements – the central executive, an attentional controller that was aided by two "slave" systems, the phonological loop and the visuo-spatial sketchpad. The phonological loop involves a store and rehearsal process, and the visuo-spatial sketchpad is assumed to be a system for maintaining and manipulating visual images (Baddeley, 1999); on the other hand, the central executive component controls the two other systems and relates them to LTM – it is also considered to be a very complex system (see Figure 5).

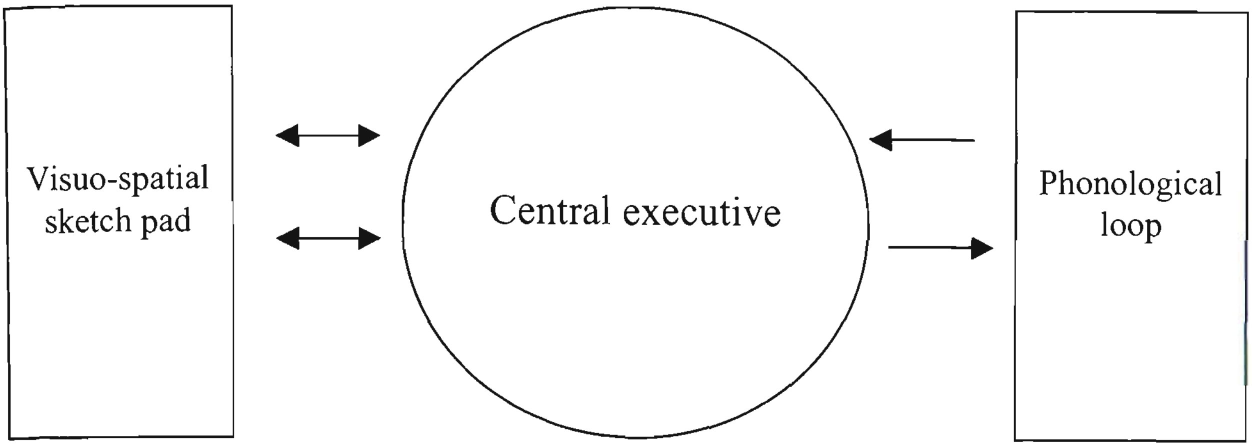

Figure 5. The Baddeley and Hitch information processing model.

From "*Essentials of Working Memory,*" by Baddeley, 1999, p. 19. East Sussex: Psychology Press Ltd.

There is still considerable debate regarding the separation of memory systems and after more than three decades of research into the working memory system and related processes, Baddeley (1999) reiterates that a "working memory approach to problems of short-term memory is not "truer" than a simple dichotomy between long- and short-term memory, but its greater flexibility allows one to capture much more of the richness of the remarkable cognitive skills that we all display" (p. 45). However, there is considerable disagreement over the function of the central executive. Baddeley (1986) had suggested that the central executive is not involved in retrieval of information from LTM. Contradictory to Baddeley's notion, current data indicates otherwise (Pashler & Carrier, 1996). Recent research suggests that the domain of the central executive has been extended to also include problem-solving, action, and LTM (Moscovitch, 1994).

C) Levels of Processing Approach (Craik & Lockhart, 1972)

Another influential model of information processing was that initially proposed by Craik and Lockhart (1972) and later developed by Craik and Tulving (1975). The "levels of processing" model suggested that rather than being separate stores, memories occur along a continuum based on the "depth of processing" of the information, which will be further elaborated under the 'Encoding' section. Craik and Lockhart referred to the hierarchy of processing stages as "depth of processing", whereby the greater the semantic or cognitive analysis of information, the greater would be the "depth" of processing of that information. They thus refuted the STM/LTM distinction that passive rehearsal of information would not enable its flow from STM to LTM. Rather, rehearsal improved memory only if the material was rehearsed in a deep and meaningful way. This approach was challenged by some researchers (e.g., Morris, Bransford, & Franks, 1977) who suggested an alternate framework, the transfer appropriate processing approach, for explaining differences in performance as a function of acquisition (semantic vs rhyme) task and type of recognition (immediate or delayed) test. However, later studies such as that by Nelson (1979) confirmed the levels of processing theory and advocated the importance of elaborate encoding so as to retain information for longer periods.

D) Systems theory of memory (Tulving, 1972, 1983)

Another division system for memory has been proposed by Endel Tulving (1972, 1983) and his colleague (Schacter & Tulving, 1994) who have suggested that memory can be divided into five major systems that differ fundamentally from one another. The five categories include procedural memory, the perceptual representational system (PRS), primary memory, episodic memory, and semantic memory. Of these five, PRS corresponds to sensory memory, primary memory relates to STM, and episodic memory and semantic memory together compare to the LTM. On the other hand, procedural memory is linked with functions such as learning associative relations, simple conditioning, and motor and cognitive skills. This division of memory systems has been scrutinized, however, it has been corroborated by studies on aging and memory as providing a good descriptive framework within which age-related changes in memory may be understood (Craik, 2000). Further support for this model comes from the evidence that many tasks are "dissociated", and hence tap into the systems differentially. Thus, if age, brain damage, or any manipulation affects performance on one task, but has no effect on a second task, it is inferred that the tasks are carried out by separate systems (Craik, 2000).

ENCODING

With the development of the information-processing perspective of memory, extensive research supports the existence of two types of memory processing systems, encoding and retrieval. Each of these two processes is governed by various factors influencing the success of the process. In this section, the elements of 'encoding' will be first considered after which the constituents of 'retrieval' will be elaborated upon.

Encoding processes have simply been defined as "subprocesses that perceive sources of new information, operate on the information using stored knowledge, and enter data (such as the perceived stimulation and records of operations) into memory" (Klatzky in Tulving 1984, p. 31). In other words, encoding begins with the perception of an event and ends with the formation of a recoded engram (Tulving, 1983). An engram or a memory trace is the product of encoding; it can also be described as the difference between the state of the memory system before and after the encoding of an event (Tulving, 1983). Similarly, Pashler and Carrier (1996), refer to encoding processes as "any mental operations performed on information arriving in the sensory systems that form memory traces of that information" (p. 14).

There are certain principles that govern the efficiency of the encoding system. Some of these principles relevant to the current research include: (A) Depth of processing, (B) Degree of elaboration, (C) Principle of congruity, and (D) Rehearsal. Each of these will be briefly described.

A) Depth of processing

In their seminar paper, Craik and Lockhart (1972) formulated the 'depth of processing' or 'levels of processing' framework to describe the manner in which items are encoded in human memory. They established that the preliminary stages of encoding are associated with analysis of physical or sensory features of stimuli, while later stages are more concerned with matching the input with stored information from previous learning. They thus conceived the notion that later stages of processing are associated with pattern recognition and the extraction of meaning and this hierarchy of processing stages was referred to as 'depth of processing', where greater depth implied a higher degree of semantic or cognitive analysis.

Craik and Lockhart reiterated that when items are processed semantically, there is a greater chance of retention and thereby better retrieval of those items. Craik and Tulving (1975) also supported this notion by suggesting that a minimal semantic analysis facilitates better recall than an extensive structural analysis that could be based on arrangement or appearance of letters. The levels of processing approach has been widely accepted as several future experiments proved the 'levels of processing' theory (e.g., Craik & Tulving, 1975; Nelson, 1979).

B) Degree of elaboration

The findings by Craik and Tulving (1975, Experiment 7) indicate that memory performance depends on the elaborateness of the encoded information. However, they argued that elaboration is beneficial "to cases where the target stimulus is compatible with the context and can thus form an integrated encoded unit with it" (p. 291). In an earlier experiment conducted by J.R. Anderson and Bower (1972), participants recalled information more accurately (72 per cent accuracy rate) when they generated elaborations to the sentences that were provided compared to participants who did not elaborate on the material (57 per cent accuracy rate). The two above studies and others such as that by Stein and Bransford (1979) indicate the importance of expanding on the given information to ensure a greater rate of retention and retrieval.

C) Principle of congruity

According to the principle of congruity put forth by Schulman (1974), memory performance is enhanced when the encoding context forms a fundamental unit with the material (such as a word) presented. Schulman explains that congruous encoding generates improved memory performance because of an elaborated memory trace, which then allows for the use of the semantic structure of memory more effectively, thus aiding retrieval. Craik and Tulving (1975) supported Schulman's theory through their experiments. They suggested that at encoding, the stimulus is interpreted in terms of the individual's previous knowledge as well as semantic memory. Thus, during retrieval, the information provided as a cue uses the semantic structure of memory once more to recollect the initial encoding. Therefore, congruous encoding leads to better memory performance according to Schulman's (1974) law.

D) Rehearsal

Rehearsal is an important technique that can enable information to be stored for a longer period. It refers to the "overt or covert process that refreshes information" (Pashler & Carrier, 1996, p. 14). It is a well-substantiated fact that rehearsal after the initial encoding of material improves the certainty of recall of that information during retrieval (for e.g., Rundus, 1971; Rundus & Atkinson, 1970). Rundus' (1971) experiments revealed that there is a close relationship between the number of rehearsals and the probability of recall (thus, the greater the number of rehearsals, the better the chances of recall). Another important result from Rundus' investigation was in relation to the effect of a distractor task and the recency effect. His results showed that counting backwards in threes (or performing another similar distractor task) blocked rehearsal. This finding had significant implications for later studies that used the distractor task in order to prevent participants from rehearsing information.

Two types of rehearsal, maintenance rehearsal and elaborative rehearsal have been identified. Maintenance rehearsal involves the repetitive review of information with little or no interpretation. Thus this is a more shallow form of rehearsal where the individual focuses on the physical nature of the stimulus rather than its meaning and is a more useful technique to store information in STM (Bjork, 1975). On the other hand, elaborative rehearsal is associated with interpreting the meaning of the stimulus and includes further processing of the material into LTM (Craik & Lockhart, 1972). On the whole, rehearsal plays an important role in the encoding process so as to aid retrieval. Therefore, efficient encoding by using any of the above mentioned strategies would lead to better retention of information. As Baddeley (1999) reiterated, "retention depends critically on the qualitative nature of encoding" (p. 268). Finally, differences in retention reflect the effects of different encoding operations.

RETRIEVAL

Retrieval is governed by the quality of the encoded and stored information. It could also be affected by other factors influencing the efficiency of recall of the stored information. However, retrieval is an important element of memory and is an essential feature that enables us to conduct our daily activities. 'Retrieval' has been defined in various ways: involving the means of using stored information (Roediger III & Guynn, 1996); a process that is aimed at revealing the contents of our memory (Klatzky, 1984); a joint product of information stored in the past and information present in the immediate cognitive environment (Tulving & Thomson, 1973); or simply as accessing previously learned material. Much research has been carried out on this end product of memory over the years and researchers have formulated several theories and arrived at many conclusions regarding the principles governing the process. As the process is inextricably linked with that of encoding, it is essential to explain both the processes in conjunction with each other.

It has been established that for retrieval to occur, two necessary conditions must be met. First, the system has to be in the 'retrieval mode' and second, an appropriate retrieval cue must be present that sets off the process (Roediger III &

Guynn, 1996; Tulving, 1983). The retrieval mode constitutes an important condition for retrieval and is the phase the individual enters while being ready to recollect some information (Tulving, 1983). This concept has been less studied compared to the 'retrieval cue'. Tulving (1983) describes the retrieval cue as ".. aspects of the individual's physical and cognitive environment that initiate and influence the process of retrieval" (p. 171). The importance of cues to enhance the recall of information has been extensively studied and confirmed (Nelson & Borden, 1977; Thomson & Tulving, 1970; Tulving & Osler, 1968; Tulving & Pearlstone, 1966; Tulving & Thomson, 1973; Tulving, 1983). Indeed, most of the principles of retrieval have been derived based on the relevance of cues in the recall process. The principles relevant to the present study will be described briefly.

A) Cue Effectiveness

The manner in which information is presented can make a difference in the likelihood of its recall. Several studies have shown the significance of cues in aiding a person's recall. Mantyla (1986) found that when participants were asked to generate their own retrieval cues for words that were presented, they were able to remember lists of up to 500-600 words. Mantyla's results also revealed that cues provided at retrieval were found to be helpful when they were both compatible and distinctive. For example, if an individual is presented with two words in a list such as coat and sheep, 'wool' may not be a distinctive cue as it can be associated with either of the target words. On the other hand, 'jacket' and 'furry animal' may serve as distinctive cues for each of the target words respectively. Thus according to this principle, a cue will be effective in aiding retrieval if and only if it is distinct from its relative cues.

B) Encoding-specificity principle

Tulving and his colleagues (Tulving & Osler, 1968; Tulving & Thomson, 1973) put forth the encoding-specificity principle to explain the nature of retrieval cues in relation to the encoding process. They explained that according to the phenomenon, "the memory trace of an event and hence the properties of (an) effective retrieval cue are determined by the specific encoding operations performed by the system on the input stimuli" (Tulving & Thomson, 1973, p. 352). In other words, what is stored in memory is influenced by what is perceived and how it is encoded, and the stored information determines what retrieval cues are effective in providing access to what is stored (Tulving & Thomson, 1973).

This principle has extensively influenced the way cued-recall experiments are conducted, manipulated, and more importantly, in helping us understand the significance and necessity of matching encoded information at the time of retrieving the information. According to the encoding specificity principle, items are encoded in a highly specific way, and effective retrieval cues must reflect that specificity (Tulving, 1983; Tulving & Thomson, 1973).

C) Transfer-appropriate processing

The postulate of transfer-appropriate processing was initiated as an alternative to the levels of processing approach. This substitute framework was necessitated as some studies suggested the need to differentiate levels of processing within the semantic level of analysis (e.g., Craik & Tulving, 1975; Schulman, 1974). It is an extension of the encoding-specificity principle but its notion is that performance on a memory test can be considered as an instance of transfer, where efficiency depends on the match of processing conditions during encoding and retrieval; the greater the match between the encoding and retrieval conditions, the greater the positive transfer (Bransford, Franks, Morris, & Strein, 1979; Morris, Bransford, & Franks, 1977).

In particular, the model suggests that it is not useful to assume that memory traces of certain items are less durable than others for those items were processed at a shallower level. Thus, based on their results, Morris et al. (1977) question the argument whether nonsemantic or shallow levels of processing are necessarily "inferior" to deeper levels of processing.

ENCODING/RETRIEVAL PARADIGM

There have been diverse efforts to explain the encoding/retrieval paradigm. It started with researchers such as James (1842-1910) and Ebbinghaus (1850-1909) in the 19th century and continues with current investigators who attempt to elaborate on the relationship between the two processes. Encoding and retrieval processes cannot be construed without taking into account the influence of one on the other (Tulving, 1983). Roediger III and Guynn (1996) also concluded that encoded information or memory traces must be "actualized through retrieval, and retrieval without memory traces is confabulation" (p. 231). The encoding and retrieval paradigm can be elucidated effectively by considering Tulving's (1983) simple but practical description of the interaction between the two processes (see Figure 6).

Retrieval Condition

		A′	B′
Encoding Condition	**A**	**A-A′**	**A-B′**
	B	**B-A′**	**B-B′**

Figure 6. The Encoding/Retrieval Paradigm.

From "*Elements of episodic memory*," by Tulving, 1983, p. 220. London: Oxford University Press.

In Figure 6, there are two encoding conditions (A and B) and two retrieval conditions (A' and B'). Consideration of the rows and only one of the columns will yield an 'encoding experiment.' The experimenter has the opportunity to manipulate the nature of encoding by changing the material and can then examine performance on a single memory test (Roediger III & Guynn, 1996). For example, the material to be encoded can be presented alone or together with another stimulus (such as a reaction time task) and recall measured alone. Here, it is essential to note that only the encoding conditions are changed, while the retrieval conditions are held constant.

On the other hand, if an individual's ability to recall information is to be measured, the 'retrieval experiment' is conducted by involving the two columns and only one of the rows shown in Figure 6 (Roediger III & Guynn, 1996). In this instance, the retrieval conditions are manipulated while the encoding conditions are held constant. A similar example to the 'encoding experiment' can be considered: to measure retrieval, the material to be remembered can be presented alone and retrieval can occur either alone or while performing a reaction time task.

Until now the manipulation of either the encoding *or* retrieval conditions has been described. However, Tulving (1983) describes a more powerful experimental design, the Encoding/Retrieval Paradigm, where there can be simultaneous manipulation of both encoding and retrieval conditions. Tulving argues that the encoding conditions A and B differ in a particular dimension, and retrieval conditions A' and B' are similar to the dimensions of the encoding conditions A' and B', respectively. Thus, according to the principles of encoding specificity and transfer-appropriate processing, performance should be best in conditions A-A' and B-B', where encoding and retrieval conditions are matched than performance in conditions A-B' and B-A', where encoding and retrieval operations vary (Roediger III & Guynn, 1996).

This encoding/retrieval paradigm was widely adopted while exploring various memory questions. Some of the different conditions which have been manipulated by various researchers while examining the interactions between encoding and retrieval processes include: (A) manipulating verbal context at encoding and retrieval, (B) manipulating the type of information emphasized at study and test (relational or item specific), (C) manipulating the participants' internal context (drug state or mood state) at study and test, (D) manipulating mental and physical operations applied to material at study and test, and (E) manipulating physical context or environmental context at study and test (Roediger III & Guynn, 1996). Only principles (A) and (B) will be elaborated as they are relevant to the present study.

A) Manipulation of verbal context

The role of verbal context in memory experiments has been studied by manipulating the context in which cues are presented at encoding and retrieval. Participants study the material in one or another context, and at test, are presented with cues similar to the context at study, or a different context. Tulving and his colleagues (Thomson & Tulving, 1970; Tulving & Osler, 1968) conducted experiments to investigate the effectiveness of cues. Tulving and Osler (1968) investigated four questions in relation to the effectiveness of retrieval cues. Firstly, they questioned whether it was possible for cue words only weakly associated with the words to be recalled, to facilitate the retrieval of the words that were presented. In support of their proposition, they found that when single cues were present at input, cued recall was approximately 70 per cent higher than non-cued recall.

The researchers' second aim was to study the effectiveness of a retrieval cue if only presented at the time of recall. Their findings indicated that when single or double cues were present at output, but not at input, recall was lower than in the absence of cues at both input and output. In the third manipulation of cues, Tulving and Osler examined whether a changed cue at recall that was "preexperimentally" equivalent to the cue at input, would be as effective as the original cue. No evidence was found to support this view. In their final experiment, the two researchers investigated whether the presence of two cues at input and output facilitated recall of the material to a greater extent compared to single cues. No support for this hypothesis was found as recall was facilitated to the same extent with the presence of either single or double cues.

The results of Tulving and Osler's experiments provide extensive support to the encoding specificity hypothesis, which states that "no cue, however strongly associated with the to-be-remembered item or otherwise related to it, can be effective unless the to-be-remembered item is specifically encoded with respect to that cue at the time of its storage" (Thomson & Tulving, 1970, p. 255).

In further experiments, Thomson and Tulving (1970) investigated the difference between the presence of strong and weak cues. They reported three experiments in which participants studied 24 words (e.g., Black) without context or along with their weak "normative associates" (e.g., train – Black) and then recalled these words under three different conditions: a) in a non-cued recall test (free recall of target words), b) in the presence of previously presented weak cues (e.g., train – target word), or c) in the presence of strong cues (e.g., white – target word) not seen at input. Results are presented in Table 6 as proportions of words recalled. Findings reveal that a retrieval cue will be effective if and only if it reinstates the original encoding of the to-be-remembered event, thus lending support to the encoding specificity hypothesis.

Table 6

Results of Thomson and Tulving's Experiment 2 (1970)

	Test context/ cues		
Study context	No cues	Weak associates	Strong associates
No cues (Black)	.49	.43	.68
Weak associates (train – Black)	.30	.82	.23

From "Retrieval Processes," by H.L. Roediger, III and M.J. Guynn, In E. L. Bjork & R. A. Bjork (Eds.), *Memory.* (p. 207). San Diego, CA: Academic Press, Inc.

(B) Manipulation of emphasis condition

There have been recent studies involving the dual-task paradigm in which participants were instructed to place emphasis on different tasks in a series of different experiments. Here, the implications of varied emphasis conditions on participants' performance were investigated (N.D. Anderson, 1999; Craik et al., 1996; Naveh-Benjamin, Craik et al., 2000). For example, Craik et al. (1996) instructed participants to perform two tasks, a memory task and a reaction time (RT) task, under three emphasis conditions: the first in which the participants were asked to pay particular emphasis to the memory task, the second in which participants were required to attend to the RT task, and a third condition, in which participants were instructed to pay equal emphasis to both tasks. Results indicate that paying emphasis to one task over the other leads to an increase in performance on the emphasized task, thus implying that emphasis on a secondary task during simultaneous encoding of words could lead to a deficiency in recall of those words. Thus, studies in relation to the two principles outlined as well as the other encoding/retrieval principles have consistently demonstrated the importance of matching contexts at encoding and retrieval to provide the highest possibility for retrieval of the items.

Experimental manipulations on encoding and retrieval processes

It is essential to understand the basic paradigm that is employed to study encoding and retrieval operations in order to understand tests of memory. This involves the creation of different learning and recall conditions. Experimenters manipulate different variables in order to study the influence of those factors upon memory operations. Some of the variables that are commonly manipulated include varying the presentation rate (held constant or varied); the nature of the to-be-remembered material (for e.g., words or sentences or pictures); mode of presentation (auditory or visual); length of material (short or long); physical conditions (for e.g., light, comfort of environment); type of task (free recall, cued recall or recognition); inclusion of a distractor task (for e.g, counting backwards by threes); or, a concurrent task (for eg., performing a RT task while recalling words). There are other variables that could also affect the encoding and retrieval operations, including the learner's ability to encode and recall information, previous experience with the material or the nature of the experiment, amount of rehearsal time provided, etc.

TYPES OF MEMORY TESTS

A variety of tests are used to study memory processes. Some of the tasks include free recall, cued recall, and recognition tasks as well as explicit and implicit memory tasks, and procedural tasks. When an individual is asked to perform a recall task, he or she is required to produce facts, words, or other items from memory; on the other hand, a recognition task requires an individual to recognize as correct (not to produce) a fact, word, or other item from memory that he or she has previously learned (Tulving & Craik, 2000). An example of a recall task could include the retrieval of an individual's friend's birthday from memory, while a recognition task could include the identification of a correct answer from four alternatives in a multiple-choice examination.

Since the two types of recall tasks, free recall and cued recall tasks are the ones employed in the current study, the nature and utility value of these tests in the dual-attention and encoding/retrieval paradigm will be elaborated.

A free recall task is one in which the participant is required to reproduce the list of previously presented items in any order. The performance measure commonly used is the number or proportion of items recalled. An effect observed when individuals are instructed to recall items immediately after the material has been presented is referred to as the recency effect (Greene, 1986). According to the recency effect, the last few items to have been presented will be recalled to a greater extent than items in the middle of the list. Thus experiments which aim to avoid this increase in recall of only a few items adopt measures to delay recall by the use of a 'distractor' task or treat the last five or so items as non-list or "buffer" items and ignore their presence in the recall protocol (Lockhart, 2000). Some examples of measures used to delay recall are the provision of numbers after presentation and prior to recall, to which the participant is required to either add three or to count numbers backward by three for a brief interval.

In cued-recall or paired-associates recall, the individual is initially presented with a list of paired items at encoding, and during retrieval, is presented with one item from each pair and required to provide the target word. It has been well established by more than three decades of memory research that cuing aids recall. This concept was primarily developed by Tulving and Pearlstone (1966). Lockhart (2000) explains that cues could be of two types: i) intra-list cues which are cues that appear along with the presentation of the target item during the presentation phase of the experiment; such cues are usually incorporated in paired-associate paradigms. ii) Another set of cues comprises the extra-list cues, which are not presented along with the target item during presentation of the material. Rather, the prompt words are provided only during the recall phase of the experiment.

Although researchers (for e.g., M.C. Anderson & Neely, 1996; Crowder, 1976; Standing, Conezio, & Haber, 1970) have found individuals' performance on recognition tasks to be superior to that of recall tasks, other investigators (Crowder, 1976; Lockhart, Craik, & Jacoby, 1976; Tulving & Thomson, 1971; Tulving, 1983) have argued that the two types of tasks are more similar to one another than many theorists are willing to concede, and that recognition of a single word can be impaired when another, associatively related, word accompanies it at the time of the test, therefore disputing the widely held view that "there is no retrieval problem in recognition memory" (Tulving & Thomson, 1971).

In clarifying the difference between recall and recognition tasks, Craik (1983) speculated that free recall requires more self-initiated processing than does cued recall, and that cued recall requires further exploration than does recognition. Furthermore, Tulving and Watkins (1973) have suggested that information retrieval in both recall and recognition is "essentially the same, a joint product of the information stored in the past and that in the immediate environment" (p. 739).

In elucidating the relation between recognition and recall Crowder (1976) reiterates that recall and recognition are very much the same except that recall involves an extra step. He explains that when recalling, the participant is required to first implicitly generate words that may have been on the list and later, the generated words are subjected to a recognition test. In contrast, on a recognition test, the experimenter provides the items to be recognized, and thereby does not involve the generation process. Thus, according to Crowder, a recall task is more difficult than a recognition task. On the other hand, Roediger III and Guynn (1996) assert that encoding/retrieval interactions occur on free-recall tests but not on recognition tests. Therefore, the type of task that is chosen could depend on the purpose of the investigation, otherwise, as some of the above-mentioned research shows, either of the tasks could be utilized in an experiment.

THE NEUROSCIENCE OF HUMAN MEMORY

"The cognitive neuroscience of human memory aims to understand how we record, retain, and retrieve experience in terms of memory systems—specific neural networks that support specific mnemonic processes" (Gabrieli, 1998, p. 87).

Investigating the brain systems associated with memory processes forms a fundamental part of enhancing the understanding of memory. At present, there is an increased focus on concurring experimental demonstration of memory processes with neuropsychological evidence and many researchers, including prominent people such as Fergus Craik and Endel Tulving have shown an increasing shift from providing a predominantly cognitive explanation for memory processes toward establishing a neurological basis for memory functions. Some of the main methods used to investigate memory processes in this manner include positron emission tomography (PET), functional magnetic resonance imaging (fMRI) and study of patients with brain lesions (Gabrieli, 1998). However, there are indications that PET and fMRI studies are limited as they derive their signals not from neural activity, but from changes in blood flow (Gabrieli, 1998).

As 'memory' is a vast field of research with many constituent processes, investigators have focused on studying specific aspects of it. A considerable amount of effort has been dedicated to studying the neuroanatomical functioning in episodic memory processes (Duzel et al., 1999; Kapur et al., 1994; Kapur et al., 1995; Moscovitch, 1994; Shallice et al., 1994). Shallice et al. (1994) have studied the brain regions associated with acquisition and retrieval of verbal episodic memory. As Tulving (1972) explained, the past experiences of an individual constitute episodic memory. Figure 7 illustrates the areas in the left and right hemispheres of the brain associated with encoding and retrieval processes. Dark sections of the brains in these images show active functioning regions. According to Tulving (2000), when people are trying to encode words in memory, the frontal and temporal cortex in the left hemisphere becomes active, but not the right hemisphere (encoding left). On the other hand, when people recall previously learned material, the right frontal cortex becomes active (retrieval right). Tulving (2000) further explains that the left hemisphere is active in retrieval, too, but to a smaller extent than the right.

Further, Shallice et al. (1994) used PET to identify components of the brain system involved in this type of memory and applied a dual-task interference paradigm to segregate brain areas associated with encoding, and a cueing paradigm to isolate areas affiliated with retrieval. They (1994) discovered that acquisition of episodic information was associated with activity in the left prefrontal cortex and the retrosplenial area, while the retrieval process was identified with activity in the right prefrontal cortex and the precuneus. The former finding in relation to encoding is also confirmed by Kapur et al., (1994) and the latter finding in relation to retrieval is also resounded in the Duzel et al. (1999) study.

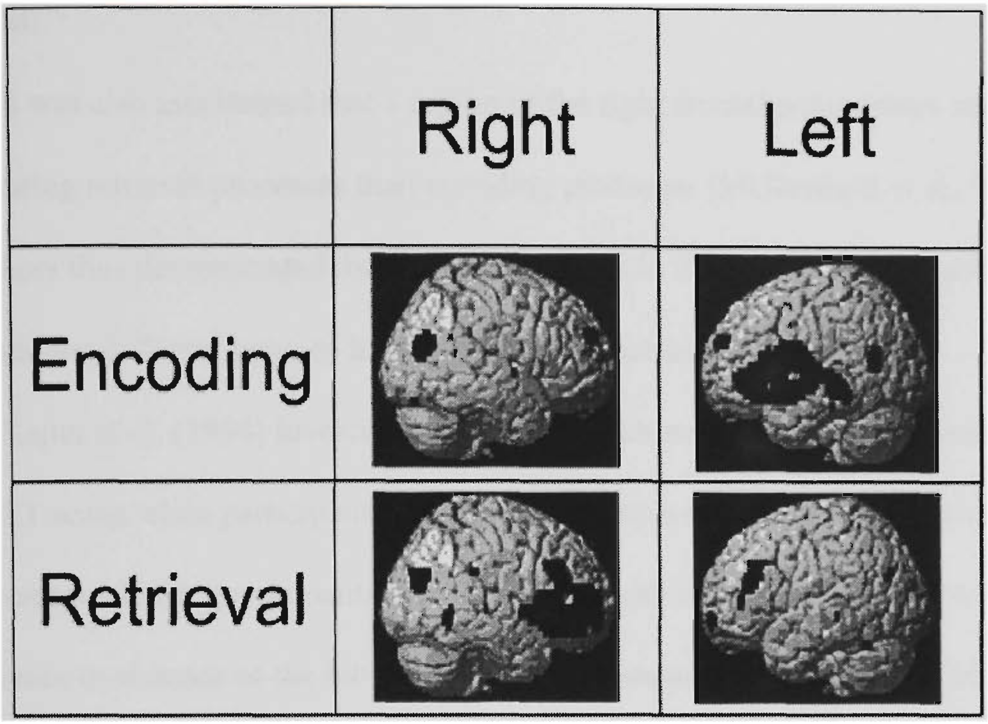

Figure 7. Brain regions associated with encoding and retrieval processes. From "Encoding and Retrieval Processes," by E.Tulving (2000). Retrieved June, 2000, from http://www.science.ca/scientists/scientistprofile.php?pID=20

In another study, brain regions that were alerted during the encoding and retrieval of faces and words were examined using fMRI (McDermott, Buckner, Petersen, Kelley, & Sanders, 1999). The researchers demonstrated that different areas in the frontal cortex were involved in the encoding and retrieval of faces and words. More specifically, they illustrated that the regions more active for words than faces were the left superior frontal cortex, left posterior inferior frontal gyrus, left parietal cortex, left ventral inferior frontal cortex, and the left lateral temporal cortex. In contrast, regions that were more active for faces than words included the right parietal cortex, right posterior inferior frontal gyrus, bilateral visual cortex, and bilateral fusiform gyrus. In brief, McDermott et al. (1999) found that words produced mainly left-lateralized activation, whereas faces elicited predominantly right-lateralized activation.

It was also ascertained that a region of the right frontal polar cortex was more active during retrieval processes than encoding processes (McDermott et al., 1999). The authors thus demonstrated that "distinct regions in the frontal cortex contribute in systematic yet different ways to human memory processing" (p. 631).

Kapur et al. (1994) investigated the neuroanatomical correlates of encoding using PET scans when participants were presented with two types of cognitive tasks. In the perceptual task, participants were presented with nouns and required to detect the presence or absence of the letter 'a', while the semantic task involved the participants categorizing nouns as living or non-living. Similar to the findings of other studies (e.g., Shallice et al., 1994), Kapur et al. (1994) found that encoding processes involve activation mainly in the left inferior prefrontal cortex.

In another study, Kapur and his colleagues (1995) determined the functional role of the prefrontal cortex in retrieval processes. They attempted to distinguish the cortical regions associated with retrieval of information (which comprises the processes involved in remembering an event) compared to ecphory (which is affiliated with the processes in the successful retrieval of stored information, Tulving, 1983) using PET scans. Kapur et al's. (1995) results showed the activation of the prefrontal cortex, primarily the right side during the retrieval process; while ecphory was associated with activation of the posterior cortical regions. These findings illustrate the varied brain regions involved in the encoding and retrieval of various types of information, further exemplifying the differences in the processes as well as the specificity in the functions of the brain regions. It can therefore be inferred that "memory processes are subserved by a wide neurocognitive network" (Kapur et al., 1994, p. 2008).

In summary, this chapter has discussed the models of memory and elaborated on the encoding and retrieval processes, also describing the encoding/retrieval paradigm. The different regions of the brain associated with encoding and retrieval processes have also been briefly discussed.

INTERACTION BETWEEN DIVIDED ATTENTION AND MEMORY PROCESSES

"There is indeed a complex and intimate relationship between memory and attention" (Cowan, 1997, p.40).

"The degree to which attentional conditions influence what we take in and remember about the world provides a window on the capacities and limitations of human information processing" (Fernandes & Moscovitch, 2000, p. 155).

Divided Attention and Memory Processes

It has been well established that memory is intimately related to attention and that the two processes are closely interwoven in the planning and monitoring of day-to-day activities (Styles, 1997). This interaction however, is not similar when the influence of *divided attention* on encoding and retrieval processes is examined. Research shows that divided attention affects input and recall of information differentially. This line of research has influenced the way encoding and retrieval processes are perceived.

It was earlier believed that that retrieval processes are involved in restoring similar operations that were active at encoding (Kolers, 1973). But if encoding and retrieval processes were similar, experimental conditions that affect one set of processes should indeed have a similar effect on the other set (Fernandes & Moscovitch, 2000). This assumption of similarity has been challenged by studies using the divided attention paradigm that have compellingly revealed that encoding and retrieval are two different memory processes (N.D. Anderson, 1999; N.D. Anderson et al., 1998; Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik et al., 1996; Fernandes & Moscovitch, 2000; Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000; Park et al., 1989). The studies have demonstrated that performance on a concurrent task during encoding reduces memory performance whereas dividing attention during retrieval has virtually no effect on memory performance.

In one of the early experiments conducted to demonstrate this, C.M.B. Anderson and Craik (1974) found that when attention is divided at encoding, memory performance markedly reduced and there is some reduction of performance on the concurrent task as well. However, the reduction in memory performance is not as great under concurrent retrieval (Johnston, Greenberg, Fisher, & Martin, 1970; Johnston, Wagstaff, & Griffith, 1972; Martin, 1970). Subsequent experiments have further established this differential impact of attention division on memory processes and the concurrent secondary task.

The Asymmetrical Effects of Divided Attention on Encoding and Retrieval

Through a series of experiment, Craik and his colleagues have made detailed observations about the nature of interaction between divided attention, encoding, and retrieval processes in human memory (N.D. Anderson, 1999; N.D. Anderson et al., 1998; Craik et al., 1996; Fernandes & Moscovitch, 2000; Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000). Specifically, they assessed the differential effects of divided attention on the encoding and retrieval operations by introducing a task at either encoding, retrieval, or both and compared performance relative to a condition in which both encoding and retrieval were conducted under full attention.

In the Craik et al. (1996) study, word recall was the primary task and a four-choice concurrent reaction time (RT) task was the secondary task to assess the influence of divided attention on the encoding and retrieval processes in human memory. Four experiments were performed with four different tasks, i.e., free-recall, cued-recall, recognition, and different instructional emphasis. The experiments will be elaborated in detail as they are significant to the present investigation.

Experiment 1 (Craik et al., 1996) was a free-recall task in which participants were provided lists of words that consisted of two-syllable common concrete nouns and required to recall the words following an interpolated arithmetic task. The secondary task was a four-choice RT task which involved a visual display on a computer screen and manual responses on the computer keyboard. The display consisted of four boxes with an asterisk (*) appearing at random in one of the boxes. The participant was required to press the corresponding key on the keyboard as quickly and accurately as possible. The memory and RT tasks were performed either alone or under a divided attention (DA) condition. Thus participants either (a) encoded and retrieved the words under Full Attention-Full Attention (FA-FA), (b) encoded the words while concurrently performing the RT task, but retrieved words under Full Attention (DA-FA), (c) encoded the words at Full Attention but retrieved it while performing the RT task (FA-DA), or, (d) performed the memory encoding and retrieval task while concurrently carrying out the RT task (DA-DA) – (NB: the RT task was performed twice in the DA-DA condition, once at encoding and once at retrieval).

The results showed that participants recalled the most number of words under the Full Attention condition. It also showed that divided attention at encoding reduced recall substantially but (relative to DA at retrieval) had a smaller effect on the slowing of the RT task. Conversely, divided attention at retrieval was associated with a smaller reduction in recall but with a larger increase in RT. In the task in which attention was divided at both encoding and retrieval, recall performance was nearly the same as that found for DA-FA but much lower than the FA-FA condition. The RT values in the DA-DA condition also echoed the values found in the corresponding phases of the other conditions, i.e., while the RT value for the DA-DA encoding phase was not affected substantially, it was influenced reliably in the DA-DA retrieval phase.

The above results are similar to Park et al. (1989) who suggested that divided attention at encoding is more disruptive to recall performance than is divided attention at retrieval. This is in spite of a significant drop in recall when attention was divided at retrieval (compared to full attention performance). On the other hand, the study found that the RT task was more affected by divided attention at retrieval than by divided attention at encoding. This experiment also showed the effect of divided attention on concurrent tasks, that is, the slowing of performance on a concurrent task because of response conflicts between the concurrent task (which was the RT task in this case) and recall. This finding is consistent with other divided attention studies that have demonstrated the limits of human attentional processing as a result of participants failing to perceive multiple stimuli accurately (e.g., Broadbent, 1958; Mitsuda, 1968; Reinitz et al., 1994). It is however essential to investigate if this strong influence of divided attention could be altered through video game training.

Experiment 2 (Craik et al., 1996) examined the influence of different emphasis instructions on memory and RT performance under full and divided attention conditions. Specifically, participants were asked to emphasise either (a) their memory performance, (b) the RT task performance, or, (c) both tasks equally. The results showed that emphasis instructions had a marked effect on memory performance under conditions of divided attention at encoding, but no effect under divided attention at retrieval. Secondary RT task performance was affected equally by emphasis at encoding and retrieval. Craik et al. explained that division of attention is associated with a reduction in memory performance along with a slowing of concurrent RT because encoding processes are consciously controlled and attention demanding. In addition, changes in emphasis could have systematic and complementary effects on both tasks.

On the other hand, the effects of divided attention at retrieval are more complex. On the one hand, there was very little effect of divided attention at retrieval on memory performance and there was also the lack of effect of emphasis instructions at retrieval. Craik et al. (1996) suggested that these results may indicate retrieval processes are in some sense obligatory or protected but require substantial resources for execution.

Experiment 3 (Craik et al., 1996) further assessed the differences between the encoding and retrieval processes using the dual-attention paradigm. This was a paired-associate study in which participants were provided with 12 pairs of unrelated nouns auditorily. In the retrieval phase, upon presentation of the 12 stimulus words, the participant provided the associated response orally. The trials were presented either under full attention and divided attention conditions.

The results for Experiment 3 were similar to that obtained in the previous experiments of the Craik et al. (1996) study. The researchers found a substantial decline in recall performance when attention was divided at encoding, relative to the full attention baseline. They attributed this to the notion that encoding is a controlled process. In contrast, divided attention at retrieval reduced recall performance only minimally which suggests that retrieval is automatic and is similar to the finding of previous studies (e.g., Baddeley et al., 1984). The results obtained in Experiment 3 were in contrast with those achieved in the free recall experiment (Experiment 1) in that retrieval costs were lower and encoding costs were higher. This is explained by the greater "support" provided by stimulus word cues at retrieval (thus reducing the costs at retrieval), whereas, at encoding, more effort would be required by the participant to form an association between the two words (thus taking up more time).

In relation to the RT performance, division of attention at both encoding and retrieval appeared to be equally affected by changes in emphasis instructions, as the concurrent RT increased by similar values in both the conditions. Craik et al. (1996) explained that RT costs were greater at encoding in Experiment 4 as it involved associating pairs of words as opposed to encoding single items in the first two experiments. They suggested that retrieval costs were lower in this experiment because of the greater 'support' provided by the stimulus word cues (p. 169). Further, they asserted memory performance and concurrent RT performance do not trade off against each other because the RT costs for both encoding and retrieval were very similar. This is also supported by the result that memory performance was still reduced to a much greater extent when attention was divided at encoding than when it was divided at retrieval.

Experiment 4 demonstrated that divided attention at acquisition would be associated with impaired encoding and thus poorer memory performance through a recognition task. This was hypothesised although it was expected that divided attention at retrieval might cause lesser impairment than Experiments 1-3 as recognition is seen to provide greater "retrieval support" than recall (Craik, 1983; Craik & McDowd, 1987). The results were similar to those found in previous experiments in that divided attention at encoding was associated with a large reduction in performance but divided attention at retrieval did not reduce performance substantially from the single-task level. Again the RT results showed the costs associated with divided attention at retrieval were not reliably greater than those found at encoding.

Overall, the memory costs were greater for encoding than for retrieval in all experiments. *Memory costs* refers to the percentage drop from the Full Attention-Full Attention condition in all cases. Similarly, memory performance was affected by divided attention at encoding in all paradigms; whereas, the smaller costs associated with divided attention at retrieval were further reduced in cued recall and recognition. The RT costs were greater when attention was divided at retrieval than those found when attention was divided at encoding. *RT costs,* also referred to as Divided Attention costs, refers to the slowing of RT above baseline, i.e., at single-task performance or, in the Full Attention condition.

The explanations offered for the differential effect of divided attention on encoding and retrieval are that encoding processes are consciously controlled and attention-demanding, and therefore require greater attentional resources; whereas retrieval processes are obligatory or protected and do not require attentional resources for their execution (Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000). Nevertheless, the execution of recall requires substantial resources as demonstrated by the large secondary task costs. Craik et al. (1996) also explain, "the final mental (and cortical) representations of events are very similar at encoding and retrieval, but the control processes involved in laying down and reactivating the representations are substantially different" (p. 160). Similarly, Fernandes and Moscovitch (2000) indicate that during encoding, memory and concurrent tasks compete for general resources, whereas during retrieval, they contend mainly for representational systems.

The findings of Craik et al. (1996) are corroborated by Anderson, N.D. et al. (1998), Fernandes and Moscovitch (2000), Naveh-Benjamin et al. (1998), and Naveh-Benjamin et al. (2000) who conducted a series of experiments to investigate the asymmetrical effects of divided attention on encoding and retrieval processes in human memory. They studied memory performance results and the contrast between the vulnerability of encoding processes and the resilience of retrieval processes to the influence of divided attention. Overall, the results confirm and extend the conclusions reached by Craik et al. (1996) by pointing to clear differences between encoding and retrieval processes: encoding is affected largely by concurrent task demands, whereas retrieval is for the most part immune to the effects of simultaneous task demands.

In summary, the results of studies investigating the differential effects of divided attention on encoding and retrieval processes have found that when attention is divided at encoding, memory performance suffers relative to full attention; likewise, concurrent encoding processes also impair secondary task performance. On the other hand, the studies have found that divided attention at retrieval does not impair memory performance substantially compared to full attention; however, it does lead to a significant cost to secondary task performance. What remains unanswered however is whether the loss of performance in the memory and RT tasks as a result of divided attention at encoding and retrieval respectively, could be reduced as a result of training to enhance the skills of divided attention. In addition, although the researchers (e.g., Craik et al., 1996; Naveh-Benjamin et al., 2000) claim quite conclusively that encoding and retrieval are entirely distinct processes in contrast to the other theories such as the encoding specificity principle (Tulving, 1982), they have not demonstrated that a cue present at encoding will *not* be effective at retrieval. This shows that encoding and retrieval processes could be different in several aspects, however, may still be similar in some, thus still holding the encoding specificity principle valid.

The Role of Reaction Time in Studies on Memory and Attention

The time an individual takes to respond to a particular stimulus may have connotations on that individual's specific cognitive abilities such as his or her ability to attend to the task as quickly and accurately as required, the ability to perform the secondary task concurrently with another task, or the motor functioning or the eye-hand coordination capacity. Kahana (2000) suggests that RT and accuracy provide complementary but correlated pictures of human behaviour. Since reaction latency can account for many of the individual differences, it has been adopted widely into the investigations in memory and attention.

In general, a RT analysis involves the inclusion of only the correct responses and the measurement of error rates. However, a speed-accuracy tradeoff may exist if faster responding is associated with high error rates (Lockhart, 2000); thus it is important in research that to report not only the correct response times, but also the error rates for each condition (especially if error rates differ among conditions) (Lockhart, 2000).

Reaction times are used extensively in the study of dual-task performance because of their robustness of measurement. A RT task is usually used as the secondary task and any variation in its performance is attributed to the divided attention condition or a lack of emphasis on this task when the participant principally focuses on the primary task. In the study of the influence of divided attention on encoding and retrieval processes, RT performance is affected differentially as discussed earlier. In summary, when there is division of attention during the encoding phase, the concurrent RT task slows significantly compared to under full attention performance and when attention is divided at retrieval, there are substantial secondary RT costs.

Effects of Practice on Divided Attention

The role of practice on dual task performance to attempt to reduce the limitation of human information processing is important. Such research would be relevant not only for theoretical importance but to assist in enhancing the capacity of individuals to perform a multitude of tasks simultaneously with greater effectiveness. Although such research could have been conducted extensively, to date, there have been only a handful of such studies (i.e., Spelke et al., 1976).

Earlier, Spelke et al. (1976) demonstrated that through extensive practice, individuals could produce substantial increases in their ability to perform comprehend stories and recall simultaneously dictated words at the same time. Similarly, other studies have shown that practice on the same or similar tasks can enhance performance. For example, Kramer, Larish, and Strayer (1995) examined training effects on learning and performance of dual tasks by young and old adults and found that training could be used in tasks with substantial memory demands. Within an information processing framework, Clark et al. (1987) studied the effects of training with video games on the response selection of elderly adults. Results showed that the practice with the video games improved RT performance suggesting that this type of training counteracts any decline in speeded responding that occurs through aging. The dearth of research in the area warrants further investigation to demonstrate the effectiveness of practice and external methods to improve and transfer the skill of divided attention is required.

On the issue of transfer of training effects to real world skills, studies on association between dual task-processing efficiency and performance in real world skills, have indicated that dual task processing skills might be non-domain specific (Avolio, Kroeck, & Panek, 1985; Crosby & Parkinson, 1979; Gopher, 1982; Kramer et al., 1995; North & Gopher, 1976). Thus improvement in divided attention skills seen in the laboratory could be transferable to other tasks such as driving (Kramer et al., 1995), flight performance (Gopher et al., 1994), or air traffic control (Greenfield, DeWinstanley et al., 1994).

Implications for the use of Video Games to Alter the Effects of Divided Attention on Encoding and Retrieval

There are important implications for the use of video games to alter the reduced interference of divided attention on encoding and retrieval performance. The findings outlined in this chapter illustrate the interaction between divided attention, encoding and retrieval processes of human memory. The interaction is such that division of attention during encoding or retrieval leads to reduced memory and RT performance, although there are variations in the pattern of this influence. The researcher argues that if video game playing could enhance the process of divided attention (after Greenfield, DeWinstanley et al., 1994) and divided attention influences the encoding and retrieval processes of human memory (after Craik et al., 1996; Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000), then playing video games could have implications for altering the encoding and retrieval processes such that memory and RT performance does not show a marked decrease due to attention division. Consequently, memory and RT performance could be enhanced even while attention is divided at encoding and retrieval by video game training.

In summary, it is clear that the effects of divided attention on encoding and retrieval processes is asymmetrical. Specifically, encoding processes are affected by division of attention to a greater extent that are retrieval processes. However, secondary task performance is more affected with attention divided at retrieval than when attention is divided at encoding. There are no studies to show whether this asymmetrical effect of divided attention could be altered through practice and development of efficient dual attention skills.

RATIONALE FOR THE PRESENT STUDY

Since the advent of simple means of one-way mass communication via the radio, silent movies, and later, the television, video games have brought arguably the first opportunity for interaction with mass media entertainment. Earlier forms of media restricted people to be passive recipients of the content and the messages. In stark contrast, the video game has created the opportunity to be active participants. This transition from a passive to an active recipient shows not only the metamorphosis that the world of media and communication has undergone, but affirms the need to fulfil the more demanding expectations of the audience to participate. More so, it emphasises the importance of investigating how these changing forms of media influence the user. It thus also becomes important to examine the effects of the interactive media such as video games on the social and psychological aspects of human beings. This leads us to the current research question.

While a considerable amount of research has been carried out to explore the social effects of video games, there has been a dearth of research into the effects of video game playing on psychological mechanisms, in particular, the beneficial aspects. Considering that this technological medium has been around for more than 30 years, this lack of findings is to say the least puzzling and exemplifies the need for investigations into the cognitive effects of video game playing.

The current study aimed to investigate the impact of video game playing on the development of divided attention skills. These skills are essential to deal with performing concurrent tasks simultaneously that are necessary in driving a car, operating heavy equipment, or controlling air traffic. Humans are extremely competent, yet they cannot pay attention to everything at the same time (Matlin, 1994). Previous studies have found that video games alter the deployment of attentional strategies (Greenfield, DeWinstanley et al., 1996). The reasons why the video game could act as a useful training medium include its high monitoring and scanning demands, a difficult manual control, dealing with events occurring simultaneously at several locations on the video screen, and discrete and timed motor responses (Gagon, 1985; Greenfield, 1984; Greenfield, DeWinstanley et al., 1996; Gopher et al., 1994). Practicing on tasks that require skills of multiple responses might transfer to help performance in tasks requiring simultaneous responses in two unrelated tasks. Further, the video game can develop faster processing of information which could be beneficial for dual task processing. Thus it is plausible to develop attention management strategies as a result of game playing and continuous practice could lead to efficient dual-attention skills, which could be transferable to other settings.

The influence of the games, however, has not been studied rigorously or extensively. Also, the impact of short-term and long-term video game training has not been explored. Thus the current study investigated the influence of this medium on enhancing divided attention skills. The result of short-term and long-term video game training on dual-task performance was also examined. Most of the previous research into the effects of video games has also employed only male participants or a larger proportion of male participants. The present study is unique as it includes only women. Previous research has also shown that the social and cognitive skills of men are more affected by video game playing than women. Thus it is argued that if video games possess the capacity to affect females' skills, then it is likely that it will also influence males' skills.

The second objective of the current study was to study the effects of video game playing on the encoding and retrieval processes of memory. Previous studies have demonstrated that division of attention at encoding, retrieval or both leads to costs associated with primary and secondary task performance (e.g., Craik et al., 1996). However, if video game training has the capacity to improve divided attention skills (after Greenfield, DeWinstanley et al., 1996), then it has the potential to alter the effects of divided attention on encoding and retrieval by reducing the costs associated primary and secondary task performance. To date, no study has explored the association between video game playing and encoding and retrieval processes. Thus the current study examined the influence of training with video games on the encoding and retrieval processes of human memory by way of reduction in associated costs.

The third aim of the study was to investigate the asymmetrical effects of video game training and divided attention on encoding and retrieval processes of human memory. Craik et al.'s (1996) research shows that the presence of a secondary task during encoding reduces the probability of recall but that secondary task performance is not greatly affected. Their study also found that memory performance when attention is divided at retrieval was also negatively affected but to a lesser extent than when attention was divided at encoding. On the other hand, the secondary task was affected to a greater extent when attention was divided at retrieval compared to the divided attention at encoding condition. It was also found that when attention was both divided at encoding and retrieval, memory and reaction time performance were similar to the levels when attention is divided at encoding and retrieval respectively (Craik et al., 1996). To date, no study has investigated if video game training or training with another method could alter the asymmetrical effects of the process of divided attention on encoding and retrieval processes. Therefore, the current explored whether training with video games could change the asymmetrical effect of divided attention on encoding and retrieval processes.

In summary, the aims of the current research were to investigate the manner in which video game playing operates on the cognitive processes of divided attention and encoding and retrieval processes of human memory. The objectives were to: (a) explore the extent to which strategic deployment of divided attention is a function of video game playing, (b) investigate the effects of video game playing on the encoding and retrieval processes of human memory, and (c) examine the asymmetrical effect of training with video games and divided attention on encoding and retrieval processes.

STATEMENT OF HYPOTHESES

The following hypotheses were examined:

1. Video game training enhances the process of divided attention.
    - (a) when attention is divided at encoding,
    - (b) when attention is divided at retrieval, and
    - (c) when attention is divided at both encoding and retrieval.

2. Video game training affects memory processes such that:
    - (a) when attention is divided at encoding, memory costs will be reduced along with concurrent secondary task costs,
    - (b) when attention is divided at retrieval, memory costs will be reduced along with concurrent secondary task costs, and
    - (c) with attention divided at both encoding and retrieval, there will be a decrease in memory costs and concurrent secondary task costs.

3. Video game training and divided attention affect encoding and retrieval processes asymmetrically such that:

    (a) when attention is divided at encoding, memory performance will drop substantially but the concurrent secondary task performance will not,

    (b) division of attention at retrieval will result in a slight drop in memory but will lead to a large increase in the concurrent secondary task performance, and

    (c) division of attention at both encoding and retrieval will result in a substantial decrease in memory performance and the concurrent secondary task performance

METHOD

Study 1

The purpose of Study 1 was to investigate the short-term training effects of video game playing on divided attention, encoding, and retrieval processes of human memory. The experimental group received one-hour video game training, whereas the control group was not exposed to any such training. The study used a 4 (Attention conditions: Full attention, Divided Attention at Encoding, Divided Attention at Retrieval, Divided Attention at Encoding and Retrieval) x 2 (Group: Trained vs Untrained groups) between-subjects design.

Participants

A total of 28 female University students aged from 17 to 25 years ($M = 19.88$, $SD = 2.39$) at a university in Melbourne, Australia participated in the current study. Although 28 participants started the experiment, three participants did not complete the posttest and their data were removed from analysis. The initial 28 participants were randomly assigned to either the experimental or the control groups. After the participant loss of 3, however, 13 experimental and 12 control participants remained in the research design. The number of participants included in the current study is similar to that employed in similar studies to the current investigation (e.g., Craik et al., 1996; Greenfield, DeWinstanley et al., 1994; Nelson & Carson, 1985). The participants were recruited based on their response to a poster advertisement on the notice boards and received AU$5.00 for each session.

Only female participants were included in the current study because little previous research was available on female video game players let alone the evaluation of potential of video games as a means of training divided attention skills. Indeed current reports suggest (IDSA, 2001) that the number of women playing video games is on the increase. It is therefore important to study the potential influence of the games on female video game players. It has also been acknowledged that men have higher levels of prior exposure and expertise through previous practice of video game play (Greenfield, DeWinstanley et al., 1994) compared to women. Hence, a greater effect of video game playing on cognitive processes is likely to be witnessed in women. If men were included in the sample, any improvement in their cognitive capacities may be confounded by their prior exposure to video games, rather than the influence of video game training on divided, encoding, and retrieval. Furthermore, if the video game training were effective, novice video game players should benefit from it as well as expert players.

All participants reported some video game experience showing increasing acceptance of this form of entertainment at home and school. The average age at which they started playing video games was 9.48 years. Approximately 24 per cent of the participants considered their ability to play video games as 'Average' and 28 per cent considered themselves 'Worse than Average' compared to the average video game player. Most of them (52%) either slightly disagreed or disagreed with having the ability to play well on a new video game.

Apparatus

Two measures were used to assess participants' level of experience with video games. This assessment was essential to obtain an estimate of participants' level of expertise in video game playing which enabled comparison with previous studies. Further, it was essential to assess participants' expertise levels to ensure random assignment of the participants to the experimental and control groups was successful.

Results showed that the experience with video games was comparable across individuals and groups. The two measures that were used to evaluate this dimension were the game 'Pac-Man' and the 'Level of Experience in Video Game Playing' questionnaire.

Pac-Man

Pac-Man, developed by Namco Ltd, was first introduced to the video game arcades at the end of 1980 and has been popular for some time. It was once the "most universally known arcade game" (Lindsey cited in Microsoft Return of Arcade, 1993-95). For the purpose of screening the level of experience in video game playing, the Pac-Man, available on Windows 95, was used.

The objective of the game was to help Pac-Man avoid the monsters and rid the screen of dots. The game is similar to a maze, with dots present throughout the maze, including some bigger dots. There are four differently coloured monsters, which move constantly throughout the maze, which the player is required to avoid. However, if the monsters "get" Pac-Man, the player loses a life (there is a maximum of three lives). With the clearance of each dot, the player achieves a score of 10, and when a bigger dot is cleared, the player obtains a score of 50. When the player clears a bigger dot, the monsters are rendered harmless and turn blue and then she has the opportunity of going behind the monsters in order to score extra points. The blue monsters increase in value: the first monster is worth 200 points, the second is worth 400 points, the third is worth 800 points and the fourth is worth 1,600 points. There are some additional points too that can be scored by clearing the different targets, such as a cherry or a strawberry, that appear as the player progresses through each level of the game. The other targets will not be explained here as no player progressed beyond the second level of the game.

Greenfield, Camaioni et al. (1996) classified players who scored 5,500 points or higher on Pac Man as experts. Since women have a lower level of video game playing expertise (Braun & Giroux, 1989; Durkin, 1995; Greenfield, 1994; Kaplan & Kaplan, 1981; Loftus et al., 1983; Wark, 1994), in the current study, a total score of 5,000 points was designated as the cut-off to determine if participant expertise was an expert.

The game was played on an IBM computer on a full screen with the four arrow keys acting as controls. No joystick was used to play the game. The game used the standard settings for the difficulty level including "three" player lives(range 1-5), the game speed set to 100 (range 50-200), normal settings for Pac-Man speed and monster movement speed

The standard settings were selected for female players who may be less skilled in video game playing (e.g., Braun & Giroux, 1989; Durkin, 1995; Greenfield, 1994; Kaplan & Kaplan, 1981; Lin et al., 1981; Loftus et al., 1983; Wark, 1994).

The game was not difficult to play and hence even those individuals with little video game experience were able to play it with relative ease. Pac-Man thus served as an appropriate screening game to assess participants' level of experience in video game playing. Players also played a game of Pac-Man in the posttest session to ascertain their level of expertise in game playing. Scores of the pre- and posttests were significantly correlated, $r\,(25) = .779, p < .0005$.

Level of Experience in Video Game Playing questionnaire

The second self-report measure on players' perceptions on their levels of video game playing expertise, 'Level of Experience in Video Game Playing' questionnaire (given in Appendix A1.1) was developed by the author by extracting factors from previous studies that have been determined to measure video game expertise, e.g., the number of games played before (Greenfield, Camaoini et al., 1996), the number of hours spent playing video games per week and the highest game scores (Greenfield, DeWinstanley et al., 1994), etc.

After the initial development of the questionnaire, a pilot study was carried out to determine the appropriateness of the questions. Based on the responses by the participants, a few minor changes were made. These changes reflect the better way participants could respond to the questions. For example, Question 2 asked: 'How many times have you played video games in the past 7 days?' Rather than responding to the number of times they had played, participants considered it more appropriate to respond to how many *hours* they had spent playing the games in the previous week. Therefore, this question was changed accordingly. Also, Question 5 asked how many times they had played the different types of games. For the same reason, as for Question 2, the change was made to query the *amount of time* participants has spent playing the games. No other changes were made.

The final version of the self-report measure included 10 items to which participants were required to determine their ability to play video games in relation to factors that characterized game playing ability. Examples of the items include: (a) the age at which participants started playing video games, (b) the amount of time they had spent playing video games over the previous week, and (c) the frequency at which they played different types of games. Participants were required to provide two types of responses: for the first part, they were to write the appropriate answer in the space provided; for the second part, participants indicated a degree of agreement on a series of statements using a 7-point Likert-type Rating Scale ranging from 1 = Strongly Agree to 7 = Strongly Disagree. Participants also completed a few demographic questions such as age, date of birth and the university course in which they were enrolled.

The same questionnaire, excluding the demographic questions (Appendix A1.2) was given in the posttest session to assess video game experience after the training sessions (for the experimental group) and to provide the reliability data (for the control group).

Video Game Assessment Questionnaire

Participants' perception of the video game used for training, Banjo Kazooie, was assessed by a self-report measure, the 'Video Game Assessment' questionnaire (Appendix B) upon completion of their video game training. The author developed this self-report measure after considering similar determinants that have been revealed to affect players' attitudes towards the game (e.g., Greenfield, Brannon et al., 1996).

The questionnaire included 13 statements to which the participants indicated the extent of agreement using a 5-point Likert-type scale ranging from 1 = Strongly Agree to 5 = Strongly Disagree. Examples of the statements include: 'I was totally absorbed in the game,' 'I found the game boring,' and 'I played the game well.

Tests of Divided Attention

An extensive search for a standardised measure of divided attention for the general population did not yield a relevant test. Although some standardised tests, for example, the 'Test of Everyday Attention' (Ridgeway, Robertson, & Ward, 1994) was found, these were mainly designed to test a clinical population. Apart from this, some components of the test, for example, the Map Search task, which requires locating particular localities within the U.S, are only applicable for testing in the United States. Hence, the Australian sample would have considerable difficulty in performing the task, not because it is extremely difficult, but because the test is not designed to suit their exposure to localities.

The literature search revealed a range of tasks used by researchers to measure divided attention. However, each task was designed to suit the nature of the particular study and it has been seldom replicated by other investigators. For example, Posner, Snyder and Davidson (1980) measured attention to different signals, however, this was specifically designed to measure attention to high and low probability targets on screen rather than divided attention per se. Greenfield, DeWinstanley et al. (1994) also used a similar task to measure divided visual attention. However, the current study required a task that was robust to measure the faculty of divided attention on its own.

Story and Comprehension test

One study that specifically tested the process of divided attention independently, and not in relation to other processes as other studies had done, was that carried out by Spelke, Hirst, and Neisser (1976). The researchers devised a test which required participants to read short stories while writing lists of words that were dictated. This test was developed to assess the faculty of divided attention in a non-clinical sample and hence considered as a suitable measure for the current study. The test could also be replicated quite easily. It also provided the means to obtain several useful scores such as the Reading Speed (as previous research has shown that video games could enhance reading skills (Greenfield, Brannon et al., 1994), Dictation Rate, Comprehension score, and number of correct words recalled (from the list of dictated words).

The author of the original test (Spelke) was contacted to ask for more details about the test. Through this process (personal communication, 5 March, 1999) it became clear that the measure needed to be modified to suit the needs of the current sample as the original stories were taken from the *New York Times* newspaper, which were more relevant for an American sample.

The stories chosen for the current study were selected on the basis that they were written for an Australian population, and more importantly, on the basis that they were of interest to women. The length of the stories was similar to those used by Spelke et al. (1976). The corresponding words for dictation were selected so that none of them were similar to the stories. They were selected from the same source (Kucera & Francis, 1967) as Spelke et al. (1976). Two stories and two dictation lists were selected and compiled, one each for the pre-test and posttest. A third story was selected for use during the practice session.

The Stories

Two stories, “Silk” and “Princess!” were selected. A third short story, “Disappearing” was used for practice session.

A section of Joy Cowley's short story, "Silk" (given in Appendix C1.1) comprising of 1,158 words, and a section of Jean Watson's short story "Princess!" (given in Appendix C1.2) comprising of 925 words were adopted from the anthology of stories 'Women's Work: Contemporary Short Stories by New Zealand Women' (McLeod & Wevers, 1987).

Due to cultural similarities between Australia and New Zealand, stories written by New Zealand authors were deemed more suitable than North American short stories. In addition, an abridged version (Appendix C1.3) of a small section of a story titled 'Disappearing' (Wood, 1989) was selected from the book 'Sudden Fiction International: sixty short-short stories' (Shapard & Thomas, 1989) for the practice test.

Story comprehension was tested by statement verification tasks (Appendix C2.1-C2.3) in which the participants verified if a series of 10 statements regarding the content is "True" or "False"

Dictation Word Lists

Words for the dictation lists were selected from the corpus of words compiled by Kucera and Francis (1967). From high frequency common concrete nouns (over an average of 200 per million words), candidate words were randomly selected excluding unfamiliar words to the Australian English speakers. From the pool of candidate words, any word that was present in the stories was excluded. It was estimated that participants would require 60 words or more for a story which takes approximately six minutes to read (based on the dictation rate of about 10 words per minute by Spelke et al.'s (1976) participants). Accordingly, 85 words (Appendix D1.1) were selected for the dictation list used during the reading of 'The Silk', and 50 words (Appendix D1.2) for dictation during the reading of 'Princess!' Twenty five words were used for dictation during the practice test (Appendix D1.3). The dictation lists were revised a few times to eliminate obscure words. The words in each list were randomised to avoid inadvertent association between contiguous words.

Divided Attention Measures

A robust measure of divided attention was required to assess this skill in the current study. The measures used by Craik, Anderson et al. (1996), Naveh-Benjamin, Craik et al. (1998), and Naveh-Benjamin, Craik et al.'s (2000) were considered appropriate as the aims of the current study were similar to their objectives. They included memory and reaction time (RT) tasks presented under full attention or dual attention conditions. The inclusion of these tasks served a dual purpose. When considered and analysed together, they could be used to assess the faculty of divided attention. On the other hand, when assessed individually, i.e., the memory task or RT task alone, each could be used to assess the memory processes of encoding and retrieval and response time accuracy, respectively. The nature and details of each of these tasks are presented in the following sections.

Memory tasks

The memory tasks were presented under different attention conditions, i.e., full attention or divided attention. The measurement of memory recall under full attention served as a basis for comparison against the divided attention tasks. The composition of the tasks will be described in this section while the nature of the assessment itself will be illustrated in the Procedure section. Two types of memory tasks were used: the Free Recall and Cued Recall. Although there are other measures such as the Recognition task to test memory processes, only the above two were selected as previous research (e.g., Tulving, 1967) has shown that the recall performance is not very different across a cued recall task or a recognition task. It is acknowledged that there are many studies that have shown performance on a recognition task to be greater than on a cued recall task. However, the aim of the current study was to determine *any* enhancement in recall. It was also beyond the scope of the current study to conduct three types of memory tests. Thus only two types of tasks, free recall and cued recall, were included.

Participants were tested under four free recall and four cued recall attention conditions in the pre- and posttest sessions, thereby making a total of eight test tasks. An aggregate of eight word lists to test memory performance under free recall and eight paired word lists to test memory performance in the cued recall condition were required. An additional four lists each for memory testing under free recall and paired-associate testing were required for the practice trials.

Two sources were utilised for the selection of words for both free recall and cued recall word lists. Both sources were similar to those used by researchers (Craik, Anderson et al., 1996; Naveh-Benjamin, Craik et al., 1998; Park, Smith et al., 1989) studying divided attention and encoding and retrieval processes of human memory. The word lists for free recall were constructed from Battig and Montague's (1969) 'Category norms for verbal items in 56 categories: A replication and extension of the Connecticut category norms.' The paired-associate word lists were established from the 'Corpus of words: computational analysis of present-day American English' (Kucera & Francis, 1967).

Word lists for Free Recall

"Words to the memory researcher are what fruit flies are to the geneticist" (Tulving, 1983, p. 146).

The criteria for choosing words was that they were common concrete nouns of one, two, three, or four syllables that were familiar to Australian English speakers. Of the 56 categories of words provided in the Battig and Montague (1969) norms, words from 36 categories were selected for establishing the word lists. The other 20 categories were excluded for different reasons. For example, the fourth category, 'A Unit of Distance' was excluded due to the inclusion of non-metric imperial units of measurement (the metric system is used in Australia). The words associated with the categories 'A Weapon' and 'A Crime' were not considered to keep terminologies used in the current study non-violent. After taking into account the extensive number of syllables in some of the categories (for example, 'An Elective Office') or because the words were proper nouns (for example, in the categories 'A Girl's First Name', 'A Male's First Name', 'A City', etc.), or simply because the words in the categories (for example, 'A Carpenter's Tool', and 'A Type of Ship') were not very familiar to the female participants in the study, further categories in the norms were excluded. The 36 categories that were selected catered to the needs of the present study and hence, words from these groups of words were incorporated in the word lists.

To develop the 12 (four each for pretests, posttests and practice trials) word lists (Appendices E1.1-E1.8 for pre- and posttest lists and E2.1-E2.4 for practice lists) to measure free recall, 136 words (8 x 12 words in each list for pre- and posttests respectively and 4 x 10 words in each list for practice trials) from the 36 categories were randomly selected among high frequency words. At least one word was chosen from each of the 36 categories. From the 136 words, 8 lists with 12 words each for the pre- and posttest conditions, and four lists with 10 words each for the practice conditions were created through random selection. It was ensured that no list contained more than one word from the same category so that categorisation of words would not be facilitated.

Paired-Associate Lists of Words

The paired-associate word lists to test memory performance under the cued recall condition were constructed from the corpus (Kucera & Francis, 1967). Twelve lists were required including four each for pretests, posttests, and practice trials (Appendices F1.1-F1.8 for pre- and posttest lists, and F2.1-F2.4 for practice lists). Each list for the pre- and posttest conditions consisted of 12 pairs of words while the practice lists comprised 10 pairs. Thus a total of 272 words were randomly selected from the corpus. The criteria for selecting the words were that the words were two, three, or four syllable common nouns with an average frequency of occurrence of 200 per million; thus words with a greater frequency of occurring were chosen. All the words were familiar to Australian English speakers.

The words were paired randomly, however, it was ascertained that there was no *obvious* association between the two words in each pair ensuring none of the cues were related to the target words. For example, Bank was paired with Wine, Teacher with Boat, Rock with Box, and so on. The basis for using weakly associated words was to avoid semantic facilitation at test. The aim of the current study was to find any differences in recall as a result of video game training rather than based on the type of cues present. Thus the usage of strong cues would have obscured any difference or improvement in recall at test as a result of the nature of the stimuli. In contrast, any improvement in word recall with the use of weakly associated cues will most likely be due to the effects of training rather than the priming by a stimulus word.

Distraction task: Arithmetic Filler task

Between the presentation of the words and the testing of recall, an arithmetic filler task that served as a distraction task was used to eliminate the effect of recency. Participants were presented with numbers between 1 - 50 at a presentation rate of one number per second and asked to add three to each digit and report the sum orally. The numbers were presented in a different order (from 1 – 50) after each task. A total of 17 number lists were prepared including eight each for pre- and posttests and one for the practice trial. Only a sample of this list is provided (Appendix G) as other lists were different combinations of similar numbers. Neither contiguous numbers nor the same number was included in the list. It was also ensured that no list consisted of an entirely difficult set of numbers.

Reaction Time Task

The Reaction Time (RT) task was used as the secondary task in the measurement of the faculty of divided attention. It was carried out while performing either encoding, retrieval, or both in free recall and cued recall conditions. In addition, the RT task was also performed once under the full attention condition to compare performance against the divided attention tasks. The RT experiments were programmed using the software program SuperLab Pro Ver. 2.01 (Cedrus Corporation, 1999), which runs on Microsoft Windows 3.1 operation system.

Each experiment consisted with of 152 trials[1]. The reaction time from the onset of to the completion of each trial was recorded by the computer program with a millisecond accuracy.

The actual experiment consisted of a four boxes with a smiley face in one of them. This smiley face moved across the boxes and the participant's task was to observe whether the smiley face appeared in the first, second, third, or fourth box and press the appropriate key, i.e., C, V, N, or M on the keyboard, respectively. This experiment was modelled after the task used in the Craik et al. (1996), Naveh-Benjamin et al. (1998), and Naveh-Benjamin et al. (2000) studies to measure response times. However, the keys were altered to allow participants to use the closest keys. Also, the smiley face was added to the boxes rather than any other pattern to add a hint of humour to the experiment and because the asterisk was a small symbol that participants could not recognise easily. The instructions page for the reaction time experiment is given in Figure 8.

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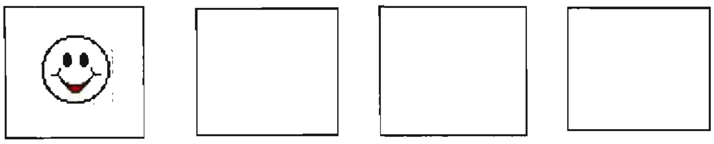
[1] The author initially created an experiment with 72 trials based on the fact that approximately 60 seconds would be required to present the words. However, after two or three individuals performed the task, it was noticed that more trials were necessary as some of the response times were very quick. Thus an experiment with 152 trials was created to cater to individuals with extremely fast reaction times. This was found to be sufficient and was utilized throughout the course of the study.

WELCOME!!

Four boxes will appear on your screen, and each time, any one of them will have an image.



One of the four keys, C, V, N, or M on the computer keyboard corresponds to the box with the image. The letter C corresponds to the first box (on the left), letter V to the second box, letter N to the third box and, M to the fourth box. Your task is to choose the correct key that corresponds to the box with the image as fast as you can each time.

Press the 'Space Bar' when you are ready to start.

Figure 8. Instructions screen for Reaction Time experiment.

Video Game

The video game used to train participants was ‘Banjo Kazooie,’ a commercially available video game (poster given in Figure 9). It was played on a Nintendo 64 (N64) console via a 34cm colour television with the aid of a Joystick present on a Nintendo 64 Control Pad. The game was chosen on a range of criteria. Firstly, it was commensurate with previous findings regarding the most preferred game by females. Research by the Australian Broadcasting Authority and Office of Film and Literature Classification (Cupitt & Stockbridge, 1996) indicates that ‘Mario Brothers,’ which is a ‘Platform’ game was the most favoured game amongst females. ‘Banjo Kazooie’ is also part of the ‘Platform’ genre, which has been shown to most appeal to the female population in comparison to the eight other genres of games. ‘Platform’ games have been described as those usually played “in the third person perspective with the player's objective being to progress to the game's end in stages or platforms" (Cupitt & Stockbridge, 1999, p.70)

Some of the other attractive features of Banjo Kazooie include: 1) the game was simple to understand and yet had varying levels of difficulty, which were not completely unattainable; 2) the game was moderately difficult for the participants to play, but with practice, the participants could improve their performance; 3) it was interesting enough to keep participants motivated after many hours of playing as it had 10 different levels for them to progress through; 4) participants' performance was quantifiable as the in-built memory system allowed for participants' scores to be retained (this was especially important for the long-term experimental group who continued each training session from where they had stopped previously); 5) it was considered a non-violent game as it is rated 'G' or for 'General' use; and 6) it was an adventure type game that has been suggested by Cupitt and Stockbridge (1999) to be the most preferred type of game by females.

It was thus deemed important to choose a game appropriate for the current research rather than one with "graphic glitz or verisimilitude" which Donchin (1995, p. 219) outlined to be some of the important attributes a game should possess when being used for research.

There were certain characteristics of the game that could aid in the development of dual attention skills. For example, it required dealing with events occurring simultaneously at several locations on the video screen, a complex control system involving the use of a range of combinations for objects on the screen to be moved, and discrete and timed motor responses. The game also had some similarity to the RT task used in the current study because of the speeded response processing required on both tasks, however, there was no such similarity with the memory task, which was carried out verbally.

The goal of the game was to achieve a maximum score, which participants could do using different moves to "defend" themselves, overcome all obstacles, gain as many rewards as possible and manage their "energy" levels efficiently. The participants were required to use the buttons only on the right side of the controller. Apart from using the four arrow keys to make the characters move in the relevant direction, there were other moves that participants had to learn, including the "A" button that could be used for jumping and the "B" button that could be used for sliding. A combination of these buttons allowed the player to make other moves. In addition, there was an "R" button on top of the controller to manage the camera angles and a "Z" button at the back of the control stick to use make the bird (Kazooie) fly.

Figure 9. Poster of 'Banjo-Kazooie.'

From "Banjo-Kazooie." Retrieved 7 October, 1999, from www.nintendo.com

Procedure

Before the collection of data, approval to conduct the study was obtained by the Human Research Ethics Committee of Victoria University (Appendix H) and the Faculty of Arts Research and Postgraduate Studies Committee (Appendix I). Participants who volunteered to take part in the study were provided with a consent form (Appendix J) to sign and indicate their willingness to participate in the study. The experiment was conducted individually in an office. The experimenter provided a brief explanation of the nature of the study and indicated that the participant would be required to perform different types of tasks and that a practice session would first be provided to familiarise the participant with the tasks. The participant was encouraged to perform the tasks to the best of her ability. She was also provided with an opportunity to clarify any questions she had regarding the procedure. Participants were advised that they were free to withdraw from the study at any time and doing so would not disadvantage them in any way. The assessment of pre- and posttest performance each took about 1 hour and 15 minutes for each participant. In addition, participants in the experimental group spent 1 hour training with the video game.

Practice Session

All participants were provided with practice on the entire range of experimental tasks prior to the pre-test. The practice session began with the test of divided attention, which consisted of reading a story at the same time as copying down dictated words. On completion of this task, the participant was required to verbally recall the words that she copied while reading the story in any order. Then the comprehension questions relating to the story were provided.

Practice was provided on the arithmetic (filler) task, wherein the participant was provided with numbers between 1-50 and asked to add three to each number and answer the sum orally.

Participants then practiced the visual Reaction Time (RT) task on the computer. The experimenter gave the instructions to the participants regarding the requirements of the task, which entailed responding to the smiley face in the box with one of the four corresponding keys, i.e., C, V, N, or M on the computer keyboard. The following instructions were provided: "On the screen, four boxes will appear and each of the four boxes has corresponding keys, i.e., C, V, N, and M respectively. In each instance, one of the boxes will contain a smiley face and your task is to press the key which corresponds to that particular box. Observe carefully as the smiley face moves and again press the corresponding key. Try and perform this task as fast as you can. Sometimes, the smiley face may appear in the same box twice or three times – you need to press the same key again. If an error is made, the smiley face will not move until you press the correct key. Continue this task until you are comfortable with it." The instruction was also presented on the screen as well to facilitate the understanding of the requirements of the task. When the participant was ready to proceed, she pressed the 'space bar' on the keyboard and placed her fingers on the relevant keys. The participant performed the task until she felt comfortable with it. On average, the participants took about two minutes to familiarize themselves with the task.

In the practice sessions for the memory tasks, the participant was provided with a description of each of the free recall and cued recall tasks followed by a practice trial on each task under full attention and divided attention conditions. Extended descriptions of these tasks are provided in the following sections. There was a one-minute interval between each of the conditions. The arithmetic (filler) task was not provided between the encoding and retrieval phases during the practice session. In order to avoid modality-specific interference, the information to-be-remembered was presented auditorily and responses during retrieval were given orally while the concurrent tasks (RT tasks) used visual stimuli and manual responses.

The manner in which the free recall and cued recall tasks were carried out was similar to studies in the area of divided attention, encoding, and retrieval process of memory (e.g., N.D. Anderson et al., 1998; N.D. Anderson, 1999; Craik et al., 1996; Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000; Park et al., 1989).

Free Recall Tasks

The participants first completed the free recall task under the Full Attention–Full Attention (FA-FA) condition. A list of 10 words was presented verbally at the rate of four seconds per word. The participant was instructed to listen carefully and form a visual image of the words. Immediately following the presentation of the last word in the list, the participant recalled the words verbally in any order while the experimenter ticked (√) those words on the list. She was instructed to say, "Pass" when her search for words was exhausted. The recall session stopped once the participant reported that she could not remember any more words. The procedures relating to the recording of words recalled and the ceasing of the experiment was followed for all memory tasks. They will therefore not be reported separately for each of the tasks.

The next task was the memory task presented under the Divided Attention–Full Attention (DA-FA) condition where the participant's attention was divided during encoding of words. The participant was verbally provided with a list of 10 words at the rate of four seconds per word that she was asked to support mnemonically with visual imagery. Here, the participant was required to perform the RT task at the same time as encoding the words. She was instructed to pay equal attention to both tasks i.e., she was to perform the RT task as quickly as possible while encoding each word by forming a visual image. At the end of the presentation of the word list, the participant was asked to stop the RT task and the experimenter stopped the RT task experiment. Then the participant orally recalled as many words as possible in any order while the experimenter recorded the responses.

The participants then practiced the third free recall task which was conducted under the Full Attention-Divided Attention (FA – DA) condition with division of attention at retrieval. The participant was presented with a list of 10 words verbally at the rate of four seconds per word and advised to use visual mnemonic strategies. The participant then performed the RT task as she retrieved as many words from memory as possible simultaneously. It was emphasised that both tasks should be given equal attention.

The final free recall task was performed under the free recall task was under the Divided Attention-Divided Attention (DA – DA) condition. Here the participant's attention was divided at both encoding and retrieval. Thus, while the list of 10 words was presented verbally one at a time and the participant encoded the words, she was also required to perform the RT task concurrently. The participant was instructed to pay equal attention to both the memory task and the RT task. She was also instructed to form mnemonic visual images for the words. The RT task was stopped after the presentation of the word list was completed. Then the experimenter started the RT task once more and the participant was required to retrieve as many words as possible at the same time as performing the RT task. The experimenter recorded the words recalled.

Cued Recall Tasks

The cued recall tasks were practiced next under the same four attention conditions as in the free recall tasks. In the Full Attention-Full Attention (FA-FA) condition, the participant was presented with 10 pairs of words at the rate of six seconds per pair and instructed to form an association between each pair. Immediately after the presentation of word pairs, the first word of each pair from the list was presented orally in random order and the participant was asked to orally recall the associated word while the experimenter recorded the responses. The participant was instructed to say, "Pass" if she did not remember the associated word.

In the Divided Attention-Full Attention (DA-FA) condition task, 10 pairs of words were presented at the rate of six seconds per pair at the same time as the participant performed the RT task. The participant was instructed to pay equal attention to both tasks, i.e., to encode the paired words by forming an association between them and perform the RT task as quickly as possible. After the word pairs were presented, the participant stopped performing the RT task. The first word of each pair was then presented in an order different to that at encoding and the participant asked to recall the associated word, while the experimenter recorded the responses.

The third task in this series involved presentation of 10 pairs of words at Full Attention with retrieval at Divided Attention (FA-DA condition). Participants were instructed to form associations between the pairs of words. Retrieval involved the recall of the associated pair of each word while performing the RT task simultaneously.

The final task in the practice session was the cued recall task in which participants were required to perform both encoding and retrieval operations in the Divided Attention-Divided Attention (DA-DA) condition. The participant encoded a list of 10 pairs and simultaneously performed the RT task. It was emphasised that she should pay equal attention to both tasks. Similarly, during the retrieval phase, the participant recalled the list of associated words while concurrently performing the RT task. This task marked the end of the practice phase of the experiment. At the end of this session, all participants were familiar with the requirements of the different tasks. No participant evidenced any difficulty in understanding and becoming accustomed to the demands of the tasks. After all the practice trials were completed, the participant was given a five-minute interval before the pre-test experimental phase.

Experimental Session

Pretest

The pretest phase followed a similar procedure and sequence of tasks as the practice session. Hence only any changes to the procedure in the presentation of the tasks will be described in this section. The order of presentation of material was counterbalanced so that one half of the participants received the material during the pre- and posttests while the other half received the material in the reverse order. In other words, one set of material that was used for the pre-test for one group was used for the posttest for the other group.

Before the start of the experimental tasks, the 'Level of Experience in Video Game Playing' questionnaire was provided. The participants were asked to fill in the questionnaire relating to their video game experience. The participants were then provided the story and comprehension test, which required writing of dictated words while simultaneously reading a story. After reading the story, the participants recalled as many words as possible and then answered the comprehension questions related to the story.

The RT task was performed next at full attention (FA) for one minute. This task was carried out to obtain a baseline measure of the participant's reaction time. Once this was completed, the participant played a game of 'Pac-Man' to provide a measure of the participant's expertise in video game playing. Participants received instructions about the game and upon starting, a short demonstration was shown automatically as part of the game about how to play the game. The players were asked to keep their fingers on the arrow keys on the computer keyboard. The players played the game for a few minutes until all three game lives were lost. The score was recorded and the players continued with the next task. The game was played after performing the RT task to ensure there was no transfer of any reaction time skills obtained from 'Pac-Man' to the RT task (as video game playing has been found to enhance reaction time performance by Clark et al. (1987), Dustman et al. (1992) and others).

Free Recall Tasks

The main goal of this set of tasks was to measure encoding and retrieval processes under full and divided attention conditions in the free recall paradigm. The manner of presentation of tasks was similar to that of the practice sessions, the only difference was the inclusion of a 30 second arithmetic filler task between study and test. There was also a one-minute interval between each of the experimental conditions in each of the free recall and cued-recall tasks.

The first free recall task in which participants encoded and retrieved a list of 12 words was performed under full attention (FA-FA). This task was performed to measure memory performance under the single-task condition and to later compare this performance with memory tasks performed under the divided attention conditions. After the words were presented, a 30-second arithmetic filler task was given. The participant then recalled as many words as possible. All responses were made verbally within a two-minute period and were recorded by the experimenter.

After an interval of one minute, the participant was presented with the next task under the Divided Attention-Full Attention (DA-FA) condition. This task was performed to measure the effects of division of attention at encoding.

The participant then performed the free recall task under the Full Attention-Divided Attention (FA-DA) condition to measure the influence of a secondary task at retrieval on memory performance. There was a reduction of about five seconds to the distractor phase to account for the time it took the experimenter to start up the RT task at the retrieval phase. This was done only when recall was carried out under a divided attention condition.

The final free recall task in this session was carried out under the Divided Attention-Divided Attention (DA-DA) condition. Attention was divided at both encoding and retrieval to assess the effects of a secondary task during both phases of recall on memory performance.

Cued Recall Tasks

The cued recall tasks began after an interval of five minutes after the free recall tasks had been completed. The aim of the cued recall paradigm was to measure the influence of full and divided attention conditions at encoding and retrieval on memory performance. Tasks were carried out in four attention conditions similar as the free recall series. Because of the need to encode two words, presentation rates were slower than in the free recall experiments. Thus the words were presented at the rate of a word pair per six seconds. A 30 second arithmetic filler task was included between study and test. There was a one-minute interval between each of the four conditions. All other procedures relating to the presentation of stimuli were similar to that used in the practice session.

The first list of 12 paired words was first presented under the Full Attention-Full Attention (FA-FA) condition to measure memory performance on a cued recall task under the single-task condition and to later compare this performance with memory tasks performed under the divided attention conditions. During encoding, the participant was instructed to form an association between each pair of words. The encoding phase was followed by a 30-second distractor phase. During the retrieval phase, the 12 stimulus words were presented again auditorily in an order different to that at encoding: this procedure was carried out for all cued recall tasks. This was done at a rate of a pair per six seconds and the participant attempted to give each associated response orally.

The participant then performed the next task under the Divided Attention-Full Attention (DA-FA) condition to obtain a measure of memory performance in the cued recall paradigm with attention divided at encoding. While the paired words were being presented, the participant simultaneously performed the RT task. The participant was instructed to form an association between each pair and also split her attention equally between the memory task and the RT task. The filler arithmetic task was given for 30 seconds and the retrieval phase then started.

Memory performance under the Full Attention-Divided Attention (FA-DA) condition was measured next wherein the participant performed the encoding task at full attention but performed retrieval at divided attention with the simultaneous performance of the RT task. During encoding, the 12 dyads were presented to the participant at full attention and she was asked to form associations between the pairs of words. The arithmetic task was then provided for 25 seconds rather than 30 seconds to account for the time it took the experimenter to start the RT experiment. The participant then recalled the associated word upon cue presentation while simultaneously performing the RT task. During the recall phase, the participant was instructed to divide her attention equally between the memory task and the RT task.

The final task in the pre-test session was memory task presented under the Divided Attention-Divided Attention (DA-DA) condition. Attention was divided at both encoding and retrieval to assess the effects of a secondary task present at both phases of recall on memory performance. During encoding, the participant was required to form association between the 12 pairs of words that were presented while concurrently performing the RT task. She was advised to share her attention equally between the two tasks. The retrieval task started after the filler arithmetic task which lasted for 25 seconds. The recall task consisted of the participant reproducing the appropriate word from memory on presentation of a cue while simultaneously performing the RT task.

Training with the Video Game

After the pre-test session, the participants in the experimental group returned to receive a one-hour training session with the video game "Banjo Kazooie" while the participants in the control group did not undergo any experimental manipulation.

The training was carried out individually with the experimental group usually returning within 2-3 days after the pre-test. The participants were seated at least 120 cm away from the television screen. Initially, participants were instructed on the use of the hand controller (as only its right and middle sections were necessary for the game), the control stick, and buttons and their positions of the different buttons. The experimenter started a new game for each participant and briefed her about the story and the goal of the game. The experimenter ensured that all participants completed the game's practice session so that they could acquire the basic skills of playing the game prior to entering the different levels of the game.

During the practice session, the player reviewed the configuration of the different buttons on the controller and practiced the different "moves" associated with the game. The participant also learned how to manoeuvre the control stick to move the characters on screen. Thus the first 15 minutes was spent as a practice session for learning how to play the game. The participant then played the game for one hour while the experimenter made observations regarding her game play, her scores and any comments she made while playing the game.

After the one-hour training session, players completed the Video-Game Assessment questionnaire. Participants were required to report how they perceived the game and provide an assessment of their video game performance.

Posttest Session

Within one week upon completion of the video game training, both experimental and control groups returned for the posttest session. The posttest session took about 35 minutes (40 minutes shorter than the pre-test session) because no practice trials were required. The aim of this session was to measure performance on the memory and RT tasks under full attention and divided attention conditions to investigate any changes in these measures from the pre-test session.

The participants were first provided with the dual-attention task of reading of a story and simultaneously writing words that were dictated by the experimenter. The procedure for performing this task was the same as that used in the pre-test session. The participants then completed the posttest version of the 'Level of Experience in Video Game Playing' questionnaire.

The remaining tasks were presented in the same order as in the pre-test. Thus, the participant was asked to perform the RT task alone for one minute and then asked to play a game of "Pac-Man" to compare performance with the pre-test score. The series of free recall and cued recall memory and RT tasks were then performed under the following attention conditions, respectively:

1) Full attention at encoding; full attention at retrieval (FA-FA)
2) Divided attention at encoding; full attention at retrieval (DA-FA)
3) Full attention at encoding; divided attention at retrieval (FA-DA)
4) Divided attention at encoding; divided attention at retrieval (DA-DA)

Summary of the Methodology

The experiment thus consisted of eight tasks carried out under either full or divided attention both under Free Recall and Cued Recall. In the divided attention conditions, the primary task was the memory task and the secondary task was the RT task and both were performed simultaneously at encoding, retrieval or both encoding and retrieval. Only the experimental groups was provided with the video game training with the game, Banjo Kazooie while the control group did not receive any training. Following the intervention, both the trained and untrained groups performed the posttests while also consisted of eight tasks performed under full and divided attention conditions both under Free Recall and Cued Recall conditions.

Study 2

The purpose of Study 2 was to investigate the effects of long-term video game training on the faculties of divided attention, encoding and retrieval processes of human memory. Specifically, the influence of a six-hour video game practice on the cognitive processes was investigated as a one-hour video game was not effective in enhancing performance on the attentional and memory tasks.

Participants

The same criteria for choosing participants in Study 1 were used in Study 2. A total of 28 female University students aged from 17 to 25 years (M = 19.80, SD = 1.94) at a university in Melbourne, Australia participated in the current study. Although 28 participants started the experiment, three participants did not complete the posttest and their data were removed from analysis. The initial 28 participants were randomly assigned to either the experimental or the control groups. After the participant loss of 3, however, 13 experimental and 12 control participants remained in the research design. The participants were recruited based on their response to a poster advertisement on the notice boards and received $5.00 for each session.

All participants had some previous experience with video games. The mean age at which this group started playing video games was 10.08 years, only slightly different to the age (9.48 years) at which individuals in Study 1 started playing video games. On a seven-point Likert-type scale ranging from 'Far Worse than Average' to 'Far Better than Average,' 32 per cent of participants considered their ability to play video games as 'Average' when compared to the average video game player, while 20 per cent of players considered themselves to be 'Slightly Worse than Average.' These statistics are comparable with the group of participants in Study 1.

Apparatus

The same material used in Study 1 was employed in Study 2. Hence the description of the material will not be repeated. The order of presentation of material was counterbalanced so that one half of the participants received the material during the pre- and posttests while the other half received the material in the reverse order.

Procedure

The manner in which the experiment was conducted was similar to that of Study 1 in relation to the memory and RT tasks and the different attention conditions under which they were performed. The details relating to the procedure will hence not be repeated. The only difference was in the amount of video game training the experimental group received. They received six hours of video game training compared to an hour of training provided to Study 1 participants.

The experiment was conducted individually. All participants initially received practice on the different tasks before being exposed to the pre-test session. In the pre-test session, participants first completed the reading and writing task in which they were required to read a story at the same as writing words dictated by the experimenter. They then completed the 'Level of Experience in Video-Game Playing' questionnaire, performed the RT task alone, and played a game of "Pac-Man." The series of free recall and cued recall memory and RT tasks were then performed under the following attention conditions, respectively:

1) Full attention at encoding; full attention at retrieval (FA-FA)
2) Divided attention at encoding; full attention at retrieval (DA-FA)

3) Full attention at encoding; divided attention at retrieval (FA-DA)
4) Divided attention at encoding; divided attention at retrieval (DA-DA)

After the pretest session, the control group did not receive any video game training. They returned approximately four weeks later for the posttest session. This time interval between the pre- and posttest sessions coincided with that of the experimental group.

Participants in the experimental group initially received a 15-minute practice session with the video game to learn the objectives of the game and the use of the different buttons on the control pad. They played for one or two hours during each training session, thus playing for a total of six hours altogether. Overall, the training phase lasted for about four weeks. The experimenter made observations of the nature of the participant's game play and noted the scores achieved during each session. On completion of the last training session, the participants completed the 'Video-Game Assessment' questionnaire to assess the game and their own performance on the game.

Within a week of the last video game training session, all participants returned to perform the posttests. The control group participants also returned during this time period to complete the posttests. The posttests were carried out in the same manner in which they were conducted in Study 1. The details of the procedure will hence not be repeated. Thus, all participants first performed the reading and writing task, in which they were required to read a story at the same as writing down words dictated by the experimenter. They then completed the posttest version of the 'Level of Experience in Video-Game Playing' questionnaire.

Participants then performed the RT task under Full Attention after which they played a game of "Pac-Man." The series of free recall and cued recall memory and

RT tasks under full attention and dual-attention conditions were then conducted in the following order:

1) Full attention at encoding; full attention at retrieval (FA-FA)
2) Divided attention at encoding; full attention at retrieval (DA-FA)
3) Full attention at encoding; divided attention at retrieval (FA-DA)
4) Divided attention at encoding; divided attention at retrieval (DA-DA)

The data from Study 1 and Study 2 were entered into SPSS v.11 and analysed separately.

RESULTS

Data Preparation

All participants' scores in the short-term training group have been included in the analysis as they did not have any missing values. In the long-term training group, one participant's score was excluded from the analysis of reaction time data as her performance was not measured due to an equipment malfunction. In both groups, participants' scores lie within a range of plus or minus 2.5 standard deviation for word recall and within plus or minus 120 ms standard deviation for Reaction Time (RT) data. For analysis of reaction times, only correct RTs greater than 100 ms were included. The first two and last two trials in the reaction time tasks were excluded from analyses. The first RT was removed as it included reading time for instructions and the preparation time to start the RT task. The second one and the last two trials were excluded to counter any delay in starting the experiment, therefore making them unreliable in accounting for any training effect. The error rate on the RT task was between 1 – 2 % on all the tasks. No transformations of the data were performed because Multivariate Analysis of Covariance is robust with regard to violations of normality (Lindman, 1974). The independent variable is training, which is a between-subjects variable (Trained vs. Untrained) and the dependent variable was performance on the recall (primary task) and RT (secondary task) tasks in the full and divided attention conditions at posttest, with the respective pretest measures as the covariates. Thus it was a mixed experimental design.

Data Analysis

An alpha level of .05 was used for all statistical inferential tests. The first purpose of the analyses was to determine whether training with video games would lead to any improvement in performance on the memory (primary task) and RT (secondary task) tasks performed under full attention and dual attention conditions. Firstly, the effect of training was assessed in a full attention condition using a Univariate Analysis of Covariance (ANCOVA). Performance on this task was used as a baseline against performance in the divided attention conditions. Further, a 3 (Attention conditions: Divided attention at encoding, Divided attention at retrieval, and Divided attention at encoding and retrieval) x 2 (Group: Trained vs. Untrained groups) mixed design Multivariate Analysis of Covariance (MANCOVA)[1] was conducted to measure performance under divided attention conditions. The posttest data formed the dependent measures with Group as the fixed factor and the pretest data included as the covariates. The memory and RT tasks performed under Free Recall and Cued Recall were analysed separately.

The second purpose of analysis was to assess memory costs and reaction time (RT) costs on the memory and RT tasks performed under full attention and dual-attention conditions. Memory costs refers to the drop in word recall in the dual attention condition from the full attention condition. RT costs refers to the slowing of RT in the divided attention condition compared to single-task performance. Thus the scores on the dual-attention tasks have been compared to that on the full attention task (cf Craik et al., 1996).

Similar to the first set of analyses, a 3 (Attention conditions: Divided attention at encoding, Divided attention at retrieval, and Divided attention at encoding and retrieval) x 2 (Group: Trained vs Untrained groups) mixed design Multivariate

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[1] Initially, a MANOVA was conducted with the pretest minus posttest score as the dependent variable. However, a MANCOVA was deemed more appropriate because of the presence of the covariate, the pretest score. A comparison of the results across the two analyses did not show any major variation except for a reduction in error and greater precision using the MANCOVA.

Analysis of Covariance (MANCOVA) was used to measure cost analysis under dual attention conditions. The posttest data formed the dependent measures with the group as the fixed factor and the pretest data included as the covariates. The memory and RT costs performed under Free Recall and Cued Recall were analysed separately. .

The third set of analyses was conducted to investigate the differential effect of video game training and divided attention on encoding and retrieval processes. Paired samples t-tests were conducted to assess the differential effect of divided attention on word recall and RT performance between full attention and divided attention conditions. Only posttest data of the trained group was considered for this analysis as the intention was to examine whether video game training would have a differential effect on any of the divided attention conditions.

The results of participants' perception of their video game performance assessed through the 'Video Game Playing Assessment' questionnaire are reported in terms of average scores and percentages.

The results for the group that was exposed to short-term video game training (Study 1) will be presented prior to the dissemination of results of the long-term video game training group (Study 2).

Analysis to show the Effect of Video Game Training on Divided Attention Tasks

Study 1

Short-term Video Game Training

Hypothesis 1

The following section presents the results of the first set of analysis conducted to examine the first hypothesis, i.e, whether video game training enhances the process of divided attention when: (a) attention is divided at encoding, (b) attention is divided at retrieval, and (c) attention is divided at both encoding and retrieval.

Story and Comprehension Test

There were four measures in this test in which participants read a story at the same time as they wrote dictated words: percentage of correct word recall (from the dictated words list), the comprehension test score, the dictation rate (words per min), and the reading speed (words per min). A 4 (Tasks: correct word recall, comprehension, dictation, reading) x 2 (Group: Trained vs Untrained) MANCOVA was conducted to assess any difference in participants' scores based on training. The posttest data formed the dependent measures with Group (Trained vs Untrained) as the fixed factor and pretest scores as the covariates. The main effect of training in the MANCOVA analysis was not statistically significant, Pillai's Trace = 0.394, $F(4,16) = 1.090$, $p > .05$. Levene's test for equality of error variance showed nonsignificant ($p > .05$) results on all four measures and therefore did not violate the homogeneity of variance assumption. The covariate results were nonsignificant in all but two cases, which suggests that the group means were adjusted using the two significant covariates. The follow-up ANCOVAs with training as the between-subjects variable did not show a statistically significant difference on any of the four dependent measures (all $p > .05$).

It is envisaged that extensive training on the tasks themselves (rather than training with an external medium such as video games) would be required to show any improvement; hence, this test was not sensitive enough to show the effects of video game training on task performance.

Memory and Reaction Time tests

Two tasks, the memory (primary task) and Reaction Time (secondary task) tasks were performed individually under Full Attention and Divided Attention conditions at both pretest and posttest. Memory performance was assessed through Free Recall and Cued Recall tasks. As expected, independent samples t-tests showed that at pretest, there were no statistically significant differences between trained and untrained groups on the Free Recall task, $t(23) = -0.524$, $p > .05$, the Cued Recall task, $t(23) = 1.160$, $p > .05$ and the RT task, $t(23) = -0.497$, $p > .05$. Hence the two groups can be deemed comparable in terms of their ability to memorise words and perform the RT task. The highest achievable word recall was 12 words in all experiments.

Full Attention

In the full attention condition, the memory task including encoding and retrieval was carried out alone (Full Attention-Full Attention, FA-FA) in the Free Recall and Cued Recall tasks. Likewise, under Full Attention, the RT task, which was performed only once, was also performed alone (FA-FA).

The univariate ANCOVA (see Table 7) for the Free Recall task performed under full attention shows that the main effect of training was not statistically significant for word recall in the Free Recall task, $F(1, 22) = .001$, $MSE = .012$, $p > .05$. Levene's test for equality of error variance showed nonsignificant results ($F(1,23) = .097$, $p > .05$) confirming the homogeneity of variance assumption, i.e., the error variance of the dependent variable was equal across trained and untrained groups. The covariate, the pretest score, was statistically significant, $F(1, 22) = 10.208$, $MSE = 21.550$, $p = .004$ indicating that the group mean was adjusted using this variable.

The univariate ANCOVA analysis (see Table 7) for the Cued Recall task performed under full attention did not show a significant main effect of training for word recall, $F(1,22) = 3.302$, $MSE = 20.967$, $p > .05$. The Levene's test showed a significant result, violating the homogeneity of variance assumption, ($F(1,23) = 6.415$, $p < .05$), however, since the main effect result was nonsignificant, no further examination of this violation is required. The covariate displayed a nonsignificant result, $F(1,22) = 3.965$, $MSE = 25.183$, $p > .05$, indicating that the group mean did not need to be adjusted by this variable.

The univariate ANCOVA results (see Table 7) for the RT task performed under full attention shows that the main effect of training did not reach statistical significance, $F(1,22) = 0.093$, $MSE = 101.513$, $p > .05$. The homogeneity of variance assumption was met as Levene's test showed nonsignificant results, $F(1,23) = .146$, $p > .05$. The covariate displayed a significant result ($F(1,22) = 138.832$, $MSE = 151198.550$, $p = .001$) indicating that the group mean was adjusted using this variable. The means and standard deviations for the posttest scores along with pretest scores (to serve as a basis for comparison) for the Free Recall, Cued Recall, and RT tasks are provided in Table 8.

Table 7

Univariate ANCOVA results for correct word recall performed under Free Recall and Cued Recall, and RT accuracy results under Full Attention ($N = 25$) in the short-term training study

Task	*F*	df	*p*
Free Recall	.000	1,22	> .05
Cued Recall	3.302	1,22	> .05
RT accuracy	.093	1,22	> .05

Table 8

Means and standard deviations for correct word recall in the Free Recall and Cued Recall tasks and RT accuracy scores (in ms) achieved in the Full Attention condition across pre- and posttests in the short-term training study ($N = 25$)

	Trained Group				Untrained Group			
Task	Pretest		Posttest		Pretest		Posttest	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Free Recall	6.46	1.61	7.38	1.61	6.92	2.64	7.58	1.83
Cued Recall	7.38	2.47	9.54	1.98	6.25	2.42	7.17	3.27
RT accuracy	496.72	69.35	475.67	72.02	519.51	148.81	487.76	101.32

Divided Attention

The MANCOVA analysis assessed whether video game training led to a difference between trained and untrained groups on the dual-attention tasks, i.e., memory and RT tasks performed under six different dual-attention conditions, three each in the Free Recall and Cued Recall tasks. The dependent variables include: a) the number of correct words recalled and b) the mean RT (in ms).

In each experiment, the memory task was the primary task and the RT task was the secondary task and both were performed simultaneously. Hence, although separate MANCOVAs were conducted for the memory and RT tasks, the results of both tasks will be reported together to ease interpretation of results.

Free Recall

The MANCOVA showed that the main effect of training was statistically significant for correct word recall in the tasks performed under Free Recall, Pillai's Trace = .435, $F\,(3,18) = 4.615$, $p = .015$. Levene's test of equality of error variance showed non-significant results for word recall under the Divided Attention - Full Attention ($p > .05$) and Full Attention-Divided Attention ($p > .05$) conditions. However, it was significant for word recall under the Divided Attention-Divided Attention ($p < .05$) condition, violating the homogeneity of variance assumption. However, since the main effect of training result was statistically significant, no further examination of the violation assumption is required for the follow-up ANCOVAs. The covariate results (Appendix K1.1) were nonsignificant in all, but two cases, indicating that the two cases were used to adjust for group means in the multivariate tests. The other covariates did not need to be used to adjust for group means[2].

The MANCOVA for RT accuracy showed that the main effect of training was statistically nonsignificant, Pillai's Trace = .305, F (4,16) = 1.758, p >.05. The Levene's test showed that there was no violation of homogeneity of variance (p > .05) for all four RT tasks performed in the three[3] dual-attention conditions. The covariate (Appendix K1.2) results show nonsignificant results in all except four cases indicating that the four cases were used to adjust for group means in the multivariate tests, while the others were not.

The follow-up ANCOVA for correct word recall with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Full Attention at Recall (DA-FA) condition showed a statistically significant effect of training, $F(1,20) = 7.478$, $MSE = 25.872$, $p = .005$ (see Table 10). The trained group recalled significantly more words at posttest ($M = 5.15$, $SD = 1.86$) than the untrained group ($M = 3.58$, $SD = 2.19$). On the other hand, follow-up ANCOVA for RT accuracy in the DA-FA condition showed the effect of training was statistically nonsignificant, $F(1, 19) = .003$, $MSE = 5.492$, $p > .05$ (see Table 12).

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[2] Although an ANOVA would need to be conducted when there are no significant covariates, the significant result of some of the covariates necessitated the use of an ANCOVA for the follow-up analysis. Also, as stated earlier (Footnote 1), initially when a MANOVA with follow-up ANOVAs was conducted, the results did not vary from the MANCOVA analysis.

[3] The RT task in the DA-DA condition was performed twice, once during DA at encoding and the other during DA at retrieval. This led to the four RT tasks along with the RT tasks at DA-FA and FA-DA.

The follow-up ANCOVA for correct word recall with group (trained vs. untrained) as the between-subjects variable in the Full Attention at Encoding - Divided Attention at Retrieval (FA-DA) condition showed that the trained group recalled significantly more words ($M = 6.38$, $SD = 1.93$) than the untrained group ($M = 4.75$, $SD = 2.05$) at posttest, $F(1,20) = 10.097$, $MSE = 28.559$, $p = .005$ (see Table 10). However, the follow-up ANCOVA for RT accuracy in the FA-DA condition did not show a reliable effect of training, $F(1,19) = .011$, $MSE = 160.057$, $p > .05$ (see Table 12).

The follow-up ANCOVA for correct word recall with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Divided Attention at Recall (DA-DA) condition showed a statistically significant effect of training, $F(1,20) = 8.923$, $MSE = 11.484$, $p = .007$ (see Table 10). The trained group recalled significantly more words at posttest ($M = 4.38$, $SD = 1.85$) compared to the untrained group ($M = 3.83$, $SD = 2.17$). On the contrary, the follow-up ANCOVA for RT accuracy in the DA-DA condition did not show a reliable effect of training at encoding, $F(1,19) = 3.231$, $MSE = 9302.333$, $p > .05$ or retrieval, $F(1,19) = .121$, $MSE = 389.228$, $p > .05$ (see Table 11). The means and standard deviations for correct word recall and RT accuracy for all three follow-up ANCOVAs are presented in Tables 10 and 12 respectively.

Table 9

Follow-up ANCOVA results for correct word recall performed under Free Recall in dual attention conditions ($N = 25$) in the short-term training study

Attention condition	*F*	df	*p*
DA-FA	7.478	1, 20	.013**
FA-DA	10.097	1, 20	.005**
DA-DA	8.923	1, 20	.007**

** denotes significance at the .01 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Table 10

Means and standard deviations for correct word recall (Free Recall) in the divided attention conditions across pre- and posttests ($N = 25$) in the short-term training study

Attention	Trained Group				Untrained Group			
condition	Pretest		Posttest		Pretest		Posttest	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
DA-FA	3.77	1.69	5.15	1.86	4.50	2.11	3.58	2.19
FA-DA	4.15	2.19	6.38	1.93	5.50	1.98	4.75	2.05
DA-DA	3.46	1.66	4.38	1.85	3.75	1.86	3.83	2.17

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Table 11

Follow-up ANCOVA results for RT accuracy performed under Free Recall in the divided attention conditions ($N = 25$) in the short-term training study

Attention condition	*F*	df	*p*
DA-FA	.003	1, 19	> .05
FA-DA	.011	1, 19	> .05
DA-DA (E)	3.231	1, 19	>.05
DA-DA (R)	.121	1,19	> .05

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Table 12

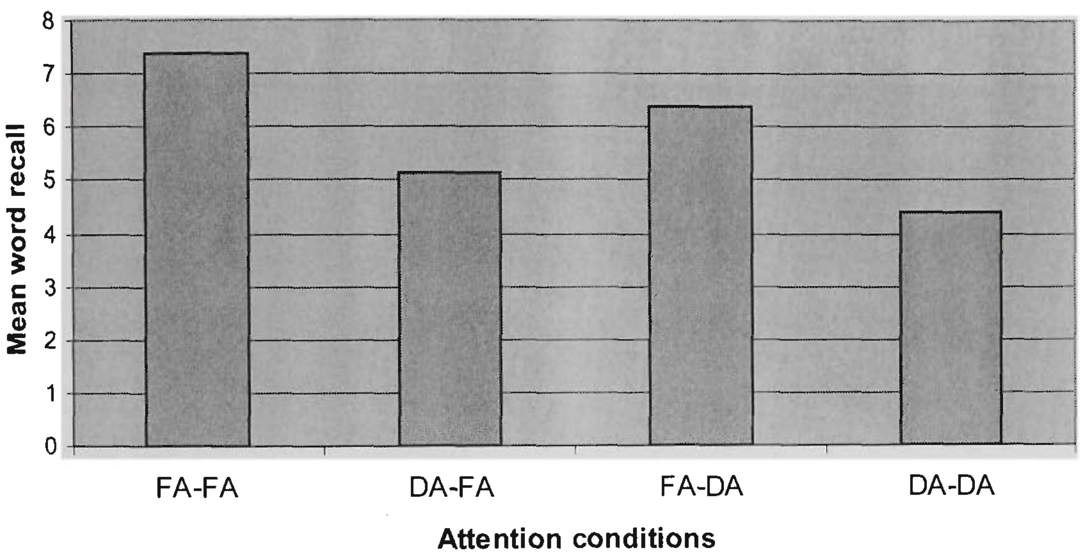
Means and standard deviations for RT accuracy (performed under Free Recall) in milliseconds in the divided attention conditions across pre- and posttests ($N = 25$) in the short-term training study

Attention	Trained Group				Untrained Group			
condition	Pretest		Posttest		Pretest		Posttest	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
DA-FA	554.52	111.84	504.84	105.98	572.64	168.03	519.79	125.51
FA-DA	783.64	260.79	643.07	236.23	655.05	249.42	582.74	181.78
DA-DA (E)	630.62	128.47	519.34	114.67	589.76	166.09	511.83	144.76
DA-DA (R)	758.95	266.73	590.83	107.65	650.32	221.26	558.05	162.19

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Comparison of performance across attention tasks

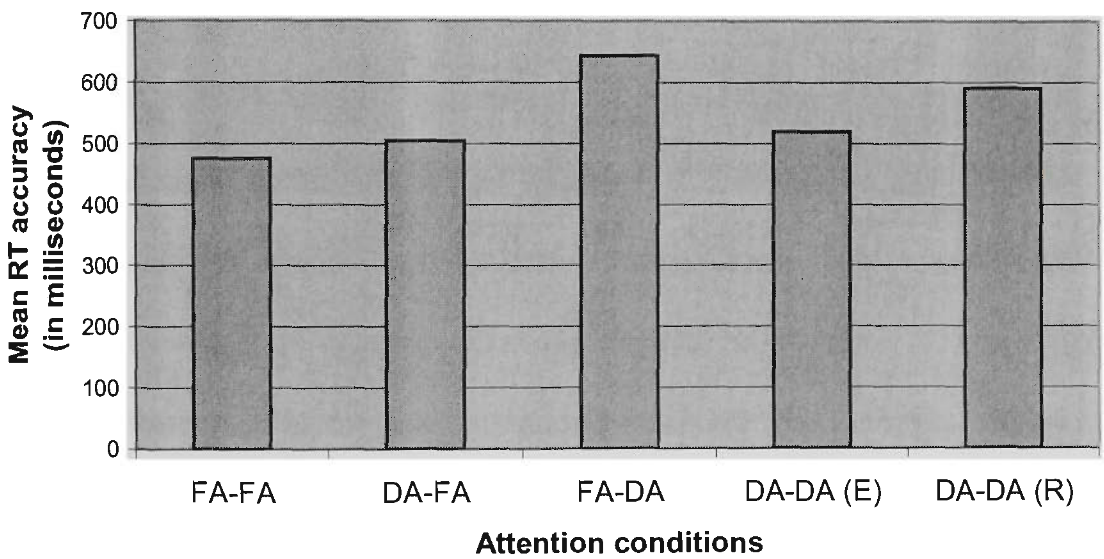
When word recall performance was compared across all the four attention conditions in the trained group, as expected, performance in the Full Attention condition was the best. Among the divided attention conditions, word recall was higher when attention was divided at retrieval followed by a higher recall when attention was divided at encoding than when attention was divided at both encoding and retrieval. Figure 10 provides a comparative illustration of the difference in mean word recall across the attention conditions in the trained group.



Note:
FA-FA (Full attention at encoding; full attention at retrieval)
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Figure 10. Comparison of mean word recall across full attention and divided attention conditions in the Free Recall task in the short-term trained group.

The difference in RT accuracy across the full attention and divided attention conditions in the trained group is illustrated in Figure 11. As expected, performance was best at Full Attention. This was followed by performance when attention was divided at encoding only, then in the RT accuracy measurement at encoding when attention was divided at both encoding and retrieval, then in the counterpart RT accuracy measurement at retrieval and last, when attention was divided at retrieval only.



Note:

FA-FA	(Full attention at encoding; full attention at retrieval)
DA-FA	(Divided attention at encoding; full attention at retrieval)
FA-DA	(Full attention at encoding; divided attention at retrieval)
DA-DA (E)	(Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R)	(Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Figure 11. Comparison of RT accuracy (in milliseconds) across full attention and divided attention conditions in the Free Recall task in the short-term trained group.

Cued Recall

The MANCOVA for correct word recall showed that the main effect of training was statistically nonsignificant in the tasks performed under Cued Recall, Pillai's Trace = .194, $F\ (3,18) = 1.444, p > .05$. Levene's test of equality of error variance showed there was no violation of the homogeneity of variance assumption under the Divided Attention-Full Attention ($p > .05$), Full Attention-Divided Attention ($p > .05$) and Divided Attention-Divided Attention ($p > .05$) conditions. The covariate results (Appendix L1.1) were nonsignificant in all, but two cases indicating that the two cases were used to adjust for group means in the multivariate tests, while the others were not.

The MANCOVA for RT accuracy showed that the main effect of training was just above statistical significance, Pillai's Trace = .415, $F\ (4,16) = 2.838, p = .06$; hence, the results are considered statistically nonsignificant. The Levene's test showed that there was no violation of homogeneity of variance ($p > .05$) for all four RT tasks performed in the four dual-attention conditions. The covariate results (Appendix L1.2) show nonsignificant results in all except five cases indicating that the five cases were used to adjust for group means in the multivariate tests, while the others were not.

The follow-up ANCOVA for correct word recall with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Full Attention at Recall (DA-FA) condition showed a statistically nonsignificant effect of training, $F(1,20) = 1.130, MSE = 4.241, p > .05$ (see Table 13). Similarly, follow-up ANCOVA for RT accuracy in the DA-FA condition showed the effect of training was statistically nonsignificant, $F(1, 19) = 1.733, MSE = 5018.906, p > .05$ (see Table 15).

The follow-up ANCOVA for correct word recall with group (trained vs. untrained) as the between-subjects variable in the Full Attention at Encoding - Divided Attention at Retrieval (FA-DA) condition showed that the effect of training was statistically nonsignificant, $F(1,20) = 1.994$, $MSE = 9.101$, $p > .05$ (see Table 13). Similarly, the follow-up ANCOVA for RT accuracy in the FA-DA condition did not show a reliable effect of training, $F(1,19) = 1.291$, $MSE = 6523.189$, $p > .05$ (see Table 15).

The follow-up ANCOVA for correct word recall with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Divided Attention at Recall (DA-DA) condition showed a statistically nonsignificant effect of training, $F(1,20) = 3.269$, $MSE = 14.383$, $p > .05$ (see Table 13). On the contrary, the follow-up ANCOVA for RT accuracy in the DA-DA condition (see Table 15) showed a reliable effect of training with attention divided at encoding, $F(1,19) = 8.319$, $MSE = 29935.436$, $p = .010$, with the trained group improving their RT significantly after training ($M = 504.12$ ms, $SD = 92.68$) compared to their nontrained group counterpart ($M = 549.51$ ms, $SD = 183.52$). Similarly, the follow-up ANCOVA for RT accuracy with attention divided at retrieval also showed a statistically significant effect of training, $F(1,19) = 7.322$, $MSE = 84679.100$, $p = .014$. Results (see Table 14) show that the trained group took lesser time to perform the RT task ($M = 607.38$ ms, $SD = 135.00$) in the posttest compared to the untrained group ($M = 644.97$ ms, $SD = 285.23$). The means and standard deviations for correct word recall and RT accuracy for all three follow-up ANCOVAs are presented in Tables 14 and 15A respectively.

Table 13

Follow-up ANCOVA results for correct word recall performed under Cued Recall in dual attention conditions ($N = 25$) in the short-term training study

Attention condition	*F*	df	*p*
DA-FA	1.130	1, 20	> .05
FA-DA	1.994	1, 20	> .05
DA-DA	3.269	1, 20	> .05

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Table 14

Means and standard deviations for correct word recall (Cued Recall) in the divided attention conditions across pre- and posttests ($N = 25$) in the short-term training study

Attention	Trained Group				Untrained Group			
condition	Pretest		Posttest		Pretest		Posttest	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
DA-FA	3.77	2.24	5.54	2.54	3.58	2.15	4.83	3.13
FA-DA	5.69	2.18	7.62	2.33	5.50	3.42	6.75	2.96
DA-DA	3.46	1.90	5.85	2.27	4.08	2.81	4.58	3.18

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Table 15

Follow-up ANCOVA results for RT accuracy performed under Cued Recall in the divided attention conditions ($N = 25$) in the short-term training study

Attention condition	*F*	df	*p*
DA-FA	1.733	1, 19	> .05
FA-DA	1.291	1, 19	> .05
DA-DA (E)	8.319	1, 19	.010**
DA-DA (R)	7.322	1,19	.014**

** denotes significance at the .01 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Table 15A

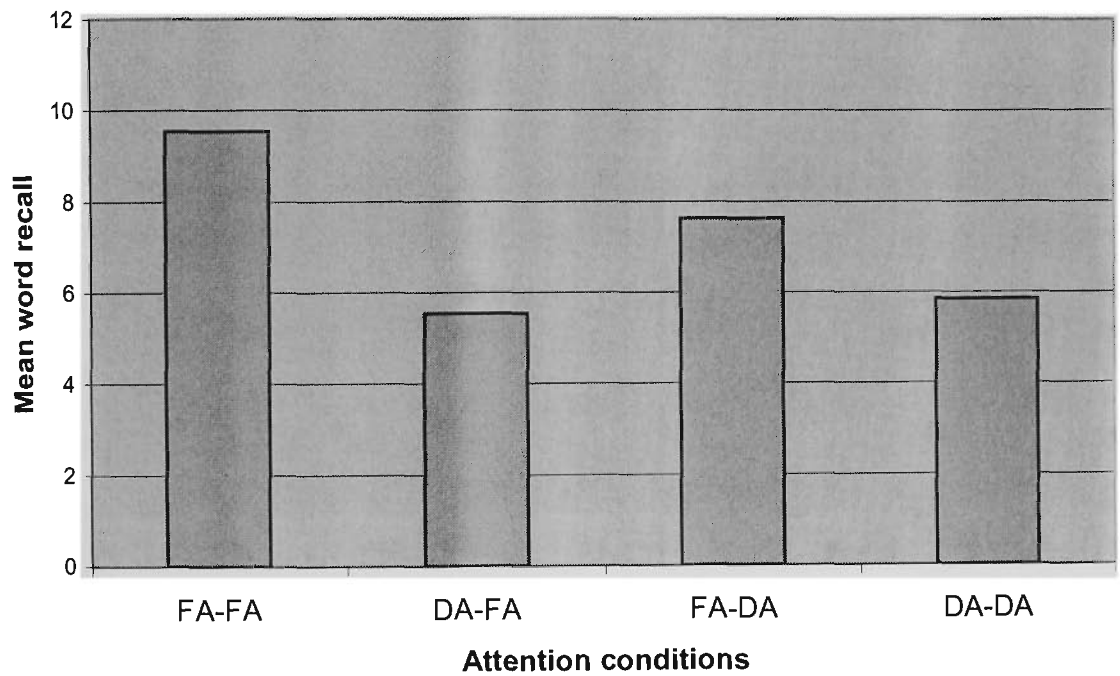
Means and standard deviations for RT accuracy (performed under Cued Recall) in milliseconds in the divided attention conditions across pre- and posttests ($N = 25$) in the short-term training study

Attention	Trained Group				Untrained Group			
condition	Pretest		Posttest		Pretest		Posttest	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
DA-FA	604.14	125.52	535.88	137.62	578.02	167.86	543.56	158.71
FA-DA	766.75	195.07	619.46	110.94	670.48	264.64	612.14	143.08
DA-DA (E)	610.45	126.81	504.12	92.68	569.39	155.19	549.51	183.52
DA-DA (R)	794.78	234.44	607.38	135.00	681.38	247.88	644.97	285.23

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Comparison of performance across attention tasks

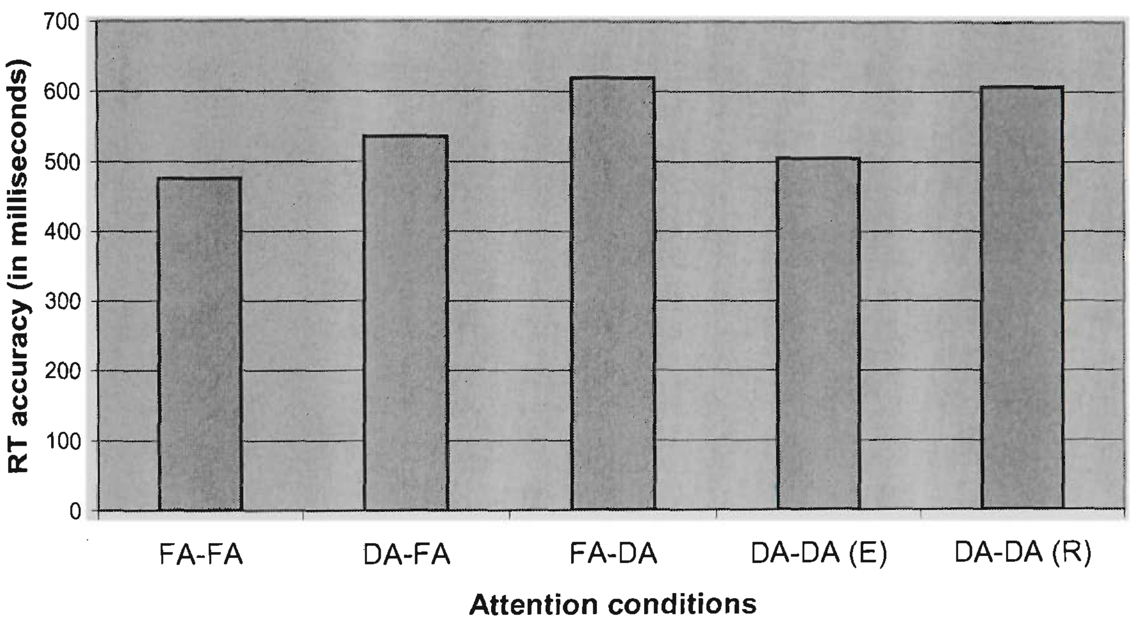
When word recall performance was compared across all the four attention conditions in the trained group, it was seen that as expected, performance in the Full Attention condition was the greatest. Among the divided attention conditions, word recall was higher when attention was divided at retrieval followed by when attention was divided at encoding and then when attention was divided at retrieval. Figure 12 provides a comparative illustration of the difference in mean word recall across the attention conditions in the trained group.



Note:
FA-FA (Full attention at encoding; full attention at retrieval)
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Figure 12. Comparison of mean word recall across full attention and divided attention conditions in the Cued Recall task in the short-term trained group.

The difference in RT accuracy across the full attention and divided attention conditions in the trained group is illustrated in Figure 13. As expected, performance was best at Full Attention. This was closely followed by the RT accuracy measurement at encoding when attention was divided at both encoding and retrieval, then when attention was divided at encoding only. Performance was worst when attention was divided at retrieval only and in the RT accuracy measurement at encoding with attention divided at both encoding and retrieval.



Note:
FA-FA (Full attention at encoding; full attention at retrieval)
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Figure 13. Comparison of RT accuracy (in milliseconds) across full attention and divided attention conditions in the Cued Recall task in the short-term trained group.

Summary of Short-Term Training Results

In summary, the results of the short-term training data analysis demonstrate that training with video games has the potential to improve skills of divided attention as displayed by some of the results wherein performance on both the primary and secondary task were enhanced after training. However, this was not the case in all dual-attention tasks, although performance did improve on either the primary or the secondary task in most of the tasks. Therefore, the results suggest that a one-hour video game training has the potential to improve divided attention skills, but perhaps the amount of training was insufficient to display more consistent results. Therefore, Study 2 was conducted to investigate the effects of video game training on divided attention skills with long-term training of six hours.

Study 2

Long-term Video Game Training

Hypothesis 1

The following section presents the results of the first set of analysis conducted to examine the first hypothesis, i.e, whether video game training enhances the process of divided attention when (a) attention is divided at encoding, (b) attention is divided at retrieval, and (c) attention is divided at both encoding and retrieval.

As stated earlier, the results of Study 1 showed the effect on video game training on some tasks but not all. It was therefore unclear whether the short-term training was effective enough to produce a behavioural change. Thus the long-term training study was conducted to investigate whether further training of participants with video games would lead to more effective behavioural change in terms the cognitive process of divided attention. The data of the long-term video game training group were analysed in the same manner as that from Study 1.

Story and Comprehension Test

There were four measures in this test in which participants read a story at the same time as they wrote dictated words: percentage of correct words recalled (from the dictated words list), the comprehension test score, the dictation rate (words per min), and the reading speed (words per min). A 4 (Tasks: correct word recall, comprehension, dictation, reading) x 2 (Group: Trained vs Untrained) MANCOVA was conducted to assess any difference to participants' scores based on training. The posttest data formed the dependent measures with Group (Trained vs Untrained) as the fixed factor and pretest scores as the covariates. The main effect of training in the MANCOVA was not significant, Pillai's Trace = .260, $F(4,13) = 1.141$, $p > .05$.

Levene's test of equality of error variance showed non-significant results on all four measures (all p's > .05). Thus there was no violation of the homogeneity of variance assumption. The covariate results were nonsignificant in all, but two cases which suggests that the two cases were used to adjust for group means in the multivariate tests, while the others were not. The follow-up ANCOVAs for all four dependent measures with training as the between-subjects variable did not show a statistically significant difference (all p's > .05).

It is envisaged that extensive training on the tasks themselves (rather than training with an external medium such as video games) would be required to show any improvement; hence, this test was not sensitive enough to show the effects of video game training on task performance.

Memory and Reaction Time Tests

Two tasks, the memory (primary task) and Reaction Time (RT) (secondary task) tasks were performed individually under Full Attention and Divided Attention conditions at both pretest and posttest. Memory recall was assessed through Free Recall and Cued Recall tasks. As expected, independent samples t-tests showed that at pretest, there were no statistically significant differences between trained and untrained groups in the Free Recall task, $t(23) = -.271, p > .05$, the Cued Recall task, $t(23) = .225, p > .05$ and the RT task, $t(22) = -.447, p > .05$. Hence the two groups can be deemed comparable in terms of their ability to memorise words and perform the RT task. The highest achievable word recall was 12 words in all experiments.

Full Attention

Similar to Study 1, the memory task including encoding and retrieval was carried out alone (Full Attention-Full Attention, FA-FA) in the Free Recall and Cued Recall tasks. Likewise, under Full Attention, the RT task, which was performed only once, was also performed alone (FA-FA).

The univariate ANCOVA (see Table 16) for the Free Recall task performed under full attention shows that the main effect of training was not statistically significant for word recall in the Free Recall task, $F\ (1, 22) = .302$, $MSE = 1.020$, $p > .05$. Levene's test for equality of error variance showed nonsignificant results ($F\ (1,23) = 1.020$, $p > .05$) confirming the homogeneity of variance assumption, i.e., the error variance of the dependent variable was equal across trained and untrained groups. The covariate, the pretest score, was statistically nonsignificant, $F\ (1, 22) = 10.208$, $MSE = 21.550$, $p = .004$ indicating that it was not used to adjust for the group mean.

The univariate ANCOVA analysis (see Table 16) for the Cued Recall task performed under full attention did not show a significant main effect of training for word recall, $F\ (1,22) = 2.291$, $p > .05$. The Levene's test showed a nonsignificant result and therefore did not violate the homogeneity of variance assumption, ($F\ (1,23) = .254$, $p > .05$). The covariate displayed a statistically significant result, $F\ (1,22) = 15.821$, $MSE = 25.892$, $p = .001$, indicating that it was used to adjust for the group mean .

The univariate ANCOVA results (see Table 7) for the RT task performed under full attention shows a statistically significant main effect of training, $F\ (1,21) = 9.864$, $p = .005$. The homogeneity of variance assumption was met as Levene's test showed nonsignificant results, $F\ (1,22) = .001$, $p > .05$. The covariate displayed a significant result ($F(1,21) = 21.393$, $MSE = 44673.387$, $p = .001$) indicating that this variable was used to adjust for the group mean. The means and standard deviations for the posttest scores along with pretest scores (to serve as a basis for comparison) for the Free Recall, Cued Recall, and RT tasks are provided in Table 17.

Table 16

Univariate ANCOVA results for correct word recall performed under Free Recall, Cued Recall tasks, and RT accuracy results under Full Attention in the long-term training study ($N = 25$)

Task	F	df	p
Free Recall	.302	1,22	> .05
Cued Recall	2.291	1,22	> .05
RT accuracy	9.864	1,22	.005**

** denotes significance at the .01 level

Table 17

Means and standard deviations for correct word recall in the Free Recall, Cued Recall tasks, and RT accuracy scores (in ms) achieved in the Full Attention condition across pre- and posttests in the long-term training study ($N = 25$)

	Trained Group				Untrained Group			
Task	Pretest		Posttest		Pretest		Posttest	
	M	SD	M	SD	M	SD	M	SD
Free Recall	7.00	2.13	8.75	1.36	7.23	2.13	8.38	2.18
Cued Recall	8.00	2.83	10.33	1.07	7.77	2.28	9.46	2.03
RT accuracy	475.88	89.71	440.65	40.57	490.96	75.44	507.98	77.49

Divided Attention

The MANCOVA analysis assessed whether video game training led to a difference between trained and untrained groups on the dual-attention tasks, i.e., memory and RT tasks performed under six different dual-attention conditions, three each in the Free Recall and Cued Recall tasks. The dependent variables include: a) the number of correct words recalled and b) the mean RT (in ms).

In each experiment, the memory task was the primary task and the RT task was the secondary task and both were performed simultaneously. Hence, although separate MANCOVAs were conducted for the memory and RT tasks, the results of both tasks will be reported together to ease interpretation of results.

Free Recall

The MANCOVA showed that the main effect of training was statistically significant for correct word recall in the tasks performed under Free Recall, Pillai's Trace = .445, $F(3,18) = 4.816, p = .012$. Levene's test of equality of error variance showed no violation of the homogeneity of variance assumption in all three divided attention conditions, i.e., Divided Attention-Full Attention ($p > .05$), Full Attention-Divided Attention ($p > .05$), and Divided Attention-Divided Attention ($p > .05$) conditions. The covariate results (Appendix M1.1) were nonsignificant ($p > .05$) in all except two cases (where $p < .05$) indicating that the two significant covariates were used to adjust for group means while the others were not.

The MANCOVA for RT accuracy showed that the main effect of training was statistically significant, Pillai's Trace = .698, $F(4,16) = 9.259, p = .001$. The Levene's test showed no violation of the homogeneity of variance assumption for two

RT tasks performed under Full Attention-Divided Attention and Divided Attention-Divided Attention (Retrieval) conditions ($p > .05$) but that the assumption was violated in the other two RT tasks performed under Divided Attention-Full Attention and Divided Attention-Divided Attention (Encoding) conditions ($p < .05$). However, since the main effect of training result was statistically significant, no further examination of the violation assumption is required for follow-up ANCOVAs. The covariate (Appendix M1.2) results show nonsignificant ($p > .05$) results in all except four cases ($p < .05$) indicating that the four covariates were used to adjust for group means while the others were not.

The follow-up ANCOVA for correct word recall with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Full Attention at Recall (DA-FA) condition showed a statistically nonsignificant effect of training, $F(1,20) = 3.454$, $MSE = 17.929$, $p > .05$ (see Table 18). Similarly, the follow-up ANCOVA for RT accuracy in the DA-FA condition also showed that the effect of training was statistically nonsignificant, $F(1, 19) = .148$, $MSE = 616.900$, $p > .05$ (see Table 20).

The follow-up ANCOVA for correct word recall with group (trained vs. untrained) as the between-subjects variable in the Full Attention at Encoding - Divided Attention at Retrieval (FA-DA) condition showed that the trained group recalled significantly more words ($M = 8.33$, $SD = 2.57$) than the untrained group ($M = 5.85$, $SD = 2.27$) at posttest, $F(1,20) = 7.492$, $MSE = 29.591$, p .013 (see Table 18). Similarly, the follow-up ANCOVA for RT accuracy in the FA-DA condition also showed a significant effect of training, $F(1,19) = 5.185$, $MSE = 47252.555$, $p = .035$ (see Table 20) with the trained group significantly improving their RT after training ($M = 506.35$ ms, $SD = 83.78$) compared to the untrained group ($M = 710.18$, $SD =$

232.64). These results indicate that performance on both primary and secondary task could be enhanced through training.

The follow-up ANCOVA for correct word recall with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Divided Attention at Retrieval (DA-DA) condition showed a statistically significant effect of training, $F(1,20) = 6.022$, $MSE = 17.123$, $p = .023$ (see Table 18). The trained group recalled significantly more words at posttest ($M = 6.17$, $SD = 2.79$) compared to the untrained group ($M = 4.54$, $SD = 2.22$). Similarly, the follow-up ANCOVA for RT accuracy in the DA-DA condition showed a reliable effect of training at encoding, $F(1,19) = 23.372$, $MSE = 20593.662$, $p = .001$) (see Table 20) with the trained group improving their RT performance considerably after training ($M = 466.71$ ms, $SD = 70.71$) compared to the untrained group ($M = 602.23$ ms, $SD = 126.97$). However, the follow-up ANCOVA for RT accuracy at retrieval did not show a statistically significant effect of training, $F(1,19) = .084$, $MSE = 1021.105$, $p > .05$).

The means and standard deviations for correct word recall and RT accuracy for all three follow-up ANCOVAs are presented in Tables 19 and 21 respectively.

Table 18

Follow-up ANCOVA results for correct word recall performed under Free Recall in dual attention conditions in the long-term training study ($N = 25$)

Attention condition	F	df	p
DA-FA	3.454	1, 20	> .05
FA-DA	7.492	1, 20	.013**
DA-DA	6.022	1, 20	.023*

* denotes significance at the .05 level; ** denotes significance at the .01 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Table 19

Means and standard deviations for correct word recall (Free Recall) in the divided attention conditions across pre- and posttests in the long-term training study ($N = 25$)

Attention	Trained Group				Untrained Group			
condition	Pretest		Posttest		Pretest		Posttest	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
DA-FA	4.00	1.80	6.08	2.71	5.00	2.92	4.54	2.26
FA-DA	5.75	2.49	8.33	2.57	5.23	2.98	5.85	2.27
DA-DA	4.50	2.58	6.17	2.79	4.85	2.08	4.54	2.22

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Table 20

Follow-up ANCOVA results for RT accuracy performed under Free Recall in the divided attention conditions in the long-term training study ($N = 25$)

Attention condition	*F*	df	*p*
DA-FA	.148	1, 19	> .05
FA-DA	5.185	1, 19	.035*
DA-DA (E)	23.372	1, 19	.000**
DA-DA (R)	.084	1,19	> .05

* denotes significance at the .05 level; ** denotes significance at the .01 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Table 21

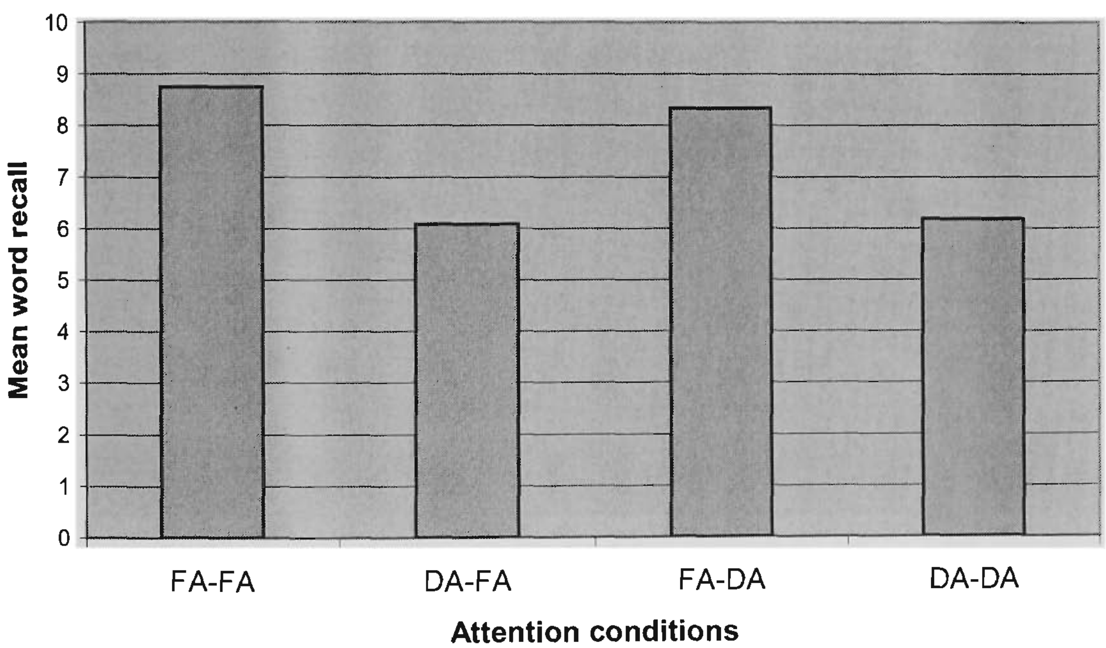
Means and standard deviations for RT accuracy (performed under Free Recall) in milliseconds in the divided attention conditions across pre- and posttests ($N = 25$) in the long-term training study

Attention condition	Trained Group				Untrained Group			
	Pretest		Posttest		Pretest		Posttest	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
DA-FA	526.70	90.75	468.28	64.03	595.78	110.75	548.34	127.59
FA-DA	763.48	428.75	506.35	83.78	733.80	293.35	710.18	232.64
DA-DA (E)	522.40	93.65	466.71	70.72	616.92	141.76	602.23	126.97
DA-DA (R)	602.05	144.65	528.16	123.29	730.16	235.71	678.56	280.87

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Comparison of performance across attention tasks

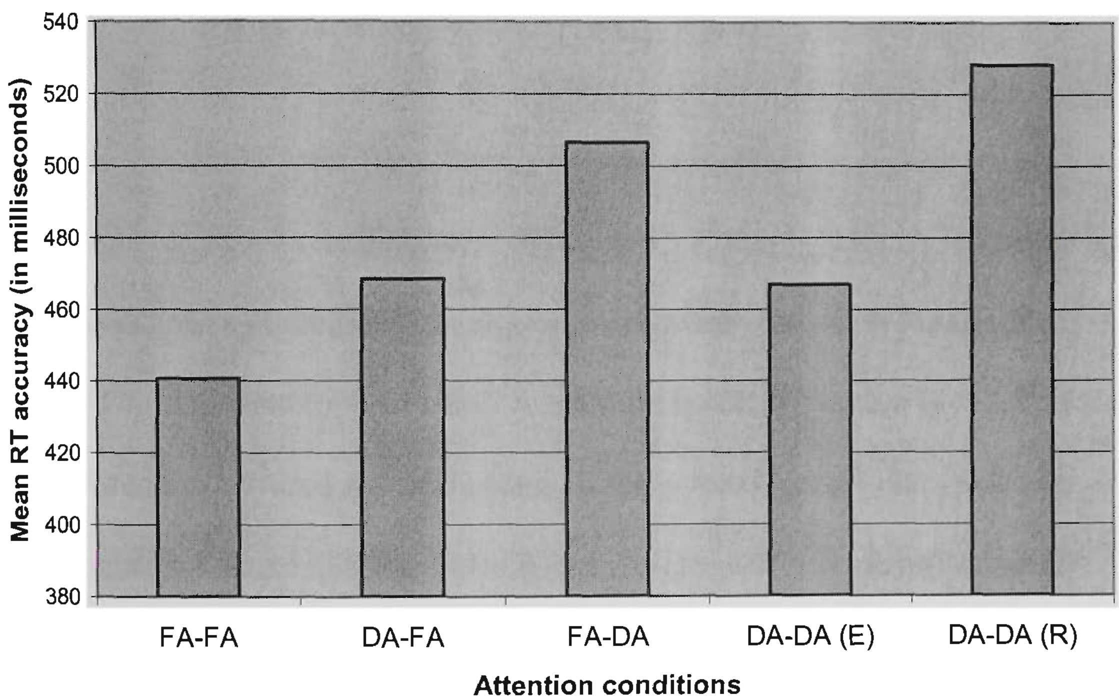
When word recall performance was compared across all the four attention conditions in the trained group, as expected, performance in the Full Attention condition was the best. This was closely followed by performance with attention was divided at retrieval. Performance was similar when attention was divided at encoding and when attention was divided at both encoding and retrieval. Figure 14 provides a comparative illustration of the difference in mean word recall across the attention conditions in the trained group.



Note:
FA-FA (Full attention at encoding; full attention at retrieval)
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Figure 14. Comparison of mean word recall across full attention and divided attention conditions in the Free Recall task in the long-term trained group.

The difference in RT accuracy across the full attention and divided attention conditions in the trained group is illustrated in Figure 15. As expected, performance was best at Full Attention. This was followed by similar levels of performance when attention was divided at encoding only and in the RT accuracy measurement at encoding when attention was divided at both encoding and retrieval. Performance was next best when attention was divided at retrieval only followed by the RT accuracy measurement at retrieval when attention was divided at both encoding and retrieval.



Note:
FA-FA (Full attention at encoding; full attention at retrieval)
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Figure 15. Comparison of RT accuracy (in milliseconds) across full attention and divided attention conditions in the Free Recall task in the long-term trained group.

Cued Recall

The MANCOVA for correct word recall showed that the main effect of training was statistically significant in the tasks performed under Cued Recall, Pillai's Trace = .566, F (3,18) = 7.829, p = .001. Levene's test of equality of error variance showed there was no violation of the homogeneity of variance assumption under the Divided Attention-Full Attention (p > .05), Full Attention-Divided Attention (p > .05) and Divided Attention-Divided Attention (p > .05) conditions. The covariate results (Appendix N1.1) were nonsignificant in all except two cases indicating that the two cases were used to adjust for group means in the multivariate tests, while the others were not.

The MANCOVA for RT accuracy showed a statistically significant main effect of training, Pillai's Trace = .454, F (4,16) = 3.329, p = .036. The Levene's test showed no violation of the homogeneity of variance assumption in the Divided Attention-Full Attention (p > .05), Full Attention-Divided Attention (p > .05), and Divided Attention-Divided Attention (Encoding) (p > .05) conditions. However, this assumption was violated in the Divided Attention-Divided Attention (Retrieval) condition (p < .05). However, since the main effect is significant, no caution needs to be exercised in the interpretation of further results. The covariate results (Appendix N1.2) show nonsignificant results in all except five cases indicating that the five cases were used to adjust for group means in the multivariate tests, while the others were not.

The follow-up ANCOVA for correct word recall with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Full Attention at Recall (DA-FA) condition showed a statistically significant effect of training, F(1,20) = 17.153, MSE = 64.691, p = .001 (see Table 22) and that the trained group recalling significantly more words (*M* = 8.58, *SD* = 2.31) than the untrained group (*M* = 4.92, *SD* = 1.98). Similarly, the follow-up ANCOVA results for RT accuracy in the DA-FA condition showed a statistically significant effect of training, $F(1, 19) = 4.825$, $MSE = 12979.064$, $p = .041$ (see Table 24) and that the trained group improved its RT performance substantially after training (*M* = 466.82 ms, *SD* = 65.13) compared to the untrained group (*M* = 585.21 ms, *SD* = 136.03).

The follow-up ANCOVA for correct word recall with group (trained vs. untrained) as the between-subjects variable in the Full Attention at Encoding - Divided Attention at Retrieval (FA-DA) condition showed a statistically significant effect of training, $F(1,20) = 13.149$, $MSE = 39.423$, $p = .002$ (see Table 22) with the trained group recalling more words at posttest (*M* = 9.33, *SD* = 2.15) than the untrained group (*M* = 6.38, *SD* = 1.76). However, the follow-up ANCOVA for RT accuracy in the FA-DA condition did not show a reliable effect of training, $F(1,19) = .070$, $MSE = 533.745$, $p > .05$ (see Table 24).

The follow-up ANCOVA for correct word recall with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Divided Attention at Retrieval (DA-DA) condition showed a statistically significant effect of training, $F(1,20) = 12.341$, $MSE = 38.340$, $p = .002$ (see Table 22). The trained group recalled more words at posttest (*M* = 8.08, *SD* = 2.15) than the untrained group (*M* = 5.08, *SD* = 2.14) (see Table 23). The follow-up ANCOVA for RT accuracy in the DA-DA condition (see Table 15) showed a reliable effect of training with attention divided at encoding, $F(1,19) = 13.524$, $MSE = 35415.846$, $p = .002$ (see Table 24)with the trained group improving their RT substantially after training (*M* = 449.23 ms, *SD* = 63.03) compared to their untrained group counterpart (*M* = 598.27 ms, *SD* = 152.16). Similarly, the follow-up ANCOVA for RT accuracy with attention divided at retrieval also showed a statistically significant effect of training, $F(1,19) = 4.627$, $MSE = 22670.215$, $p = .045$ (see Table 24) with the trained group taking lesser time to perform the RT task in the posttest ($M = 520.74$ ms, $SD = 104.65$) compared to the untrained group ($M = 708.67$ ms, $SD = 288.17$).

The means and standard deviations for correct word recall and RT accuracy for all three follow-up ANCOVAs are presented in Tables 23 and 25 respectively.

Table 22

Follow-up ANCOVA results for correct word recall performed under Cued Recall in dual attention conditions in the long-term training study ($N = 25$)

Attention condition	*F*	df	*p*
DA-FA	17.153	1, 20	.001**
FA-DA	13.149	1, 20	.002**
DA-DA	12.341	1, 20	.002**

** denotes significance at the .01 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Table 23

Means and standard deviations for correct word recall (Cued Recall) in the divided attention conditions across pre- and posttests in the long-term training study ($N = 25$)

Attention	Trained Group				Untrained Group			
condition	Pretest		Posttest		Pretest		Posttest	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
DA-FA	5.33	2.06	8.58	2.31	4.62	2.26	4.92	1.98
FA-DA	7.25	3.36	9.33	2.15	6.23	2.65	6.38	1.76
DA-DA	5.75	3.19	8.08	2.15	5.00	2.30	5.08	2.14

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Table 24

Follow-up ANCOVA results for RT accuracy performed under Cued Recall in the divided attention conditions in the long-term training study ($N = 25$)

Attention condition	F	df	p
DA-FA	4.825	1, 19	.041*
FA-DA	.070	1, 19	> .05
DA-DA (E)	13.524	1, 19	.002**
DA-DA (R)	4.627	1,19	.045*

* denotes significance at the .05 level; ** denotes significance at the .01 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Table 25

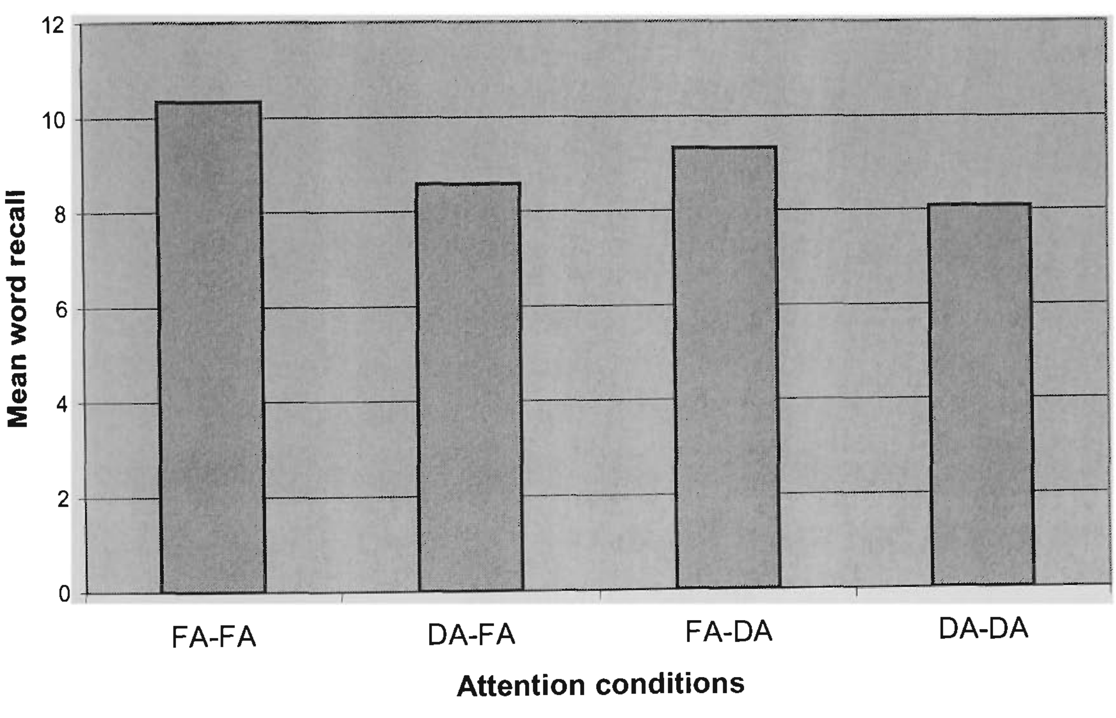
Means and standard deviations for RT accuracy (performed under Cued Recall) in milliseconds in the divided attention conditions across pre- and posttests ($N = 25$) in the long-term training study

Attention condition	Trained Group				Untrained Group			
	Pretest		Posttest		Pretest		Posttest	
	M	SD	M	SD	M	SD	M	SD
DA-FA	547.04	95.36	466.82	65.13	613.64	150.36	585.21	136.03
FA-DA	636.57	156.45	553.88	145.85	782.48	360.81	692.69	286.39
DA-DA (E)	565.13	165.36	449.23	63.03	641.71	147.39	598.27	152.16
DA-DA (R)	692.88	258.51	520.74	104.65	759.61	300.28	708.67	288.17

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Comparison of performance across attention tasks

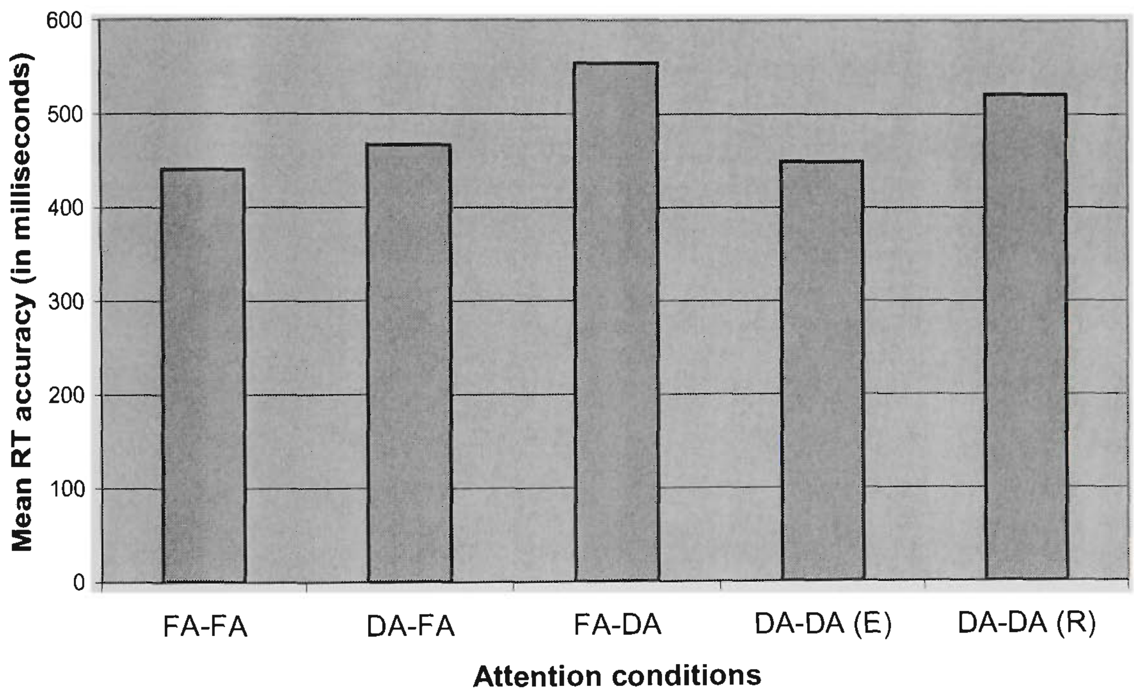
When word recall performance was compared across all the four attention conditions in the trained group, as expected, performance in the Full Attention condition was the best. This was closely followed by performance with attention was divided at retrieval. Performance was similar when attention was divided at encoding and when attention was divided at both encoding and retrieval. Figure 16 provides a comparative illustration of the difference in mean word recall across the attention conditions in the trained group.



Note:
FA-FA (Full attention at encoding; full attention at retrieval)
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Figure 16. Comparison of mean word recall across full attention and divided attention conditions in the Cued Recall task in the long-term trained group.

The difference in RT accuracy across the full attention and divided attention conditions in the trained group is illustrated in Figure 17. As expected, performance was best at Full Attention. This was followed by similar levels of performance when attention was divided at encoding only and in the RT accuracy measurement at encoding when attention was divided at both encoding and retrieval. Performance was next best in the RT accuracy measurement at retrieval when attention was divided at both encoding and retrieval followed by when attention was divided at retrieval only.



Note:
FA-FA (Full attention at encoding; full attention at retrieval)
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Figure 17. Comparison of RT accuracy (in milliseconds) across full attention and divided attention conditions in the Cued Recall task in the long-term trained group.

Summary of Long-Term Training Results

In summary, the results of the long-term training data analysis demonstrate that training with video games could provide strategies to improve skills of divided attention as displayed by most of the results wherein performance on both the primary and secondary task were enhanced after training. This was the case in both the Free Recall and Cued Recall experiments. The few tasks (e.g., RT task in the Full Attention-Divided Attention condition, Cued Recall) on which performance did not improve substantially after training demonstrate the difficult nature of the task condition wherein even a six-hour training with video games is not able to enhance performance. Overall, the results suggest that a six-hour training with video games could significantly enhance performance on dual-attention tasks thus improving skills of divided attention.

Analysis to show the Effect of Video Game Training on Memory Processes

Study 1

Hypothesis 2

The following section presents the results of the analysis that examined the second hypothesis, i.e., whether video game training affects memory processes such that: (a) when attention is divided at encoding, memory costs will be reduced along with concurrent secondary task costs, (b) when attention is divided at retrieval, memory costs will be reduced along with concurrent secondary task costs, and (c) with attention divided at both encoding and retrieval, there will be a decrease in memory costs and concurrent secondary task costs.

The data was analysed[4] to examine this hypothesis by considering the costs associated with memory performance under the three divided attention conditions and investigating whether there would be a reduction in these costs as a result of video game training. Memory costs refers to the drop in word recall in the dual attention condition from the full attention condition. RT costs refers to the slowing of RT in the divided attention condition compared to single-task performance. Thus the scores on the dual-attention tasks have been compared to that on the full attention task. In all experiments, the memory task was the primary task and the RT task was the secondary task.

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[4] I am extremely grateful to Professor Fergus Craik for providing important suggestions regarding the analysis of this data. His suggestions helped simplify the complexity of the data.

This analysis would demonstrate the influence of video game training and divided attention on encoding and retrieval processes. Further, the secondary task costs were also examined to investigate if video game training could reduce these costs as well. Thus the analyses provide answers to the following questions: (a) whether training with video games enhances memory performance when attention is divided at both encoding and retrieval by way of reducing memory costs, and (b) whether secondary task costs, i.e., RT costs can be reduced through video game training.

Similar to the analysis of data for Hypothesis 1, a 3 (Attention conditions: Divided attention at encoding, Divided attention at retrieval, and Divided attention at encoding and retrieval) x 2 (Group: Trained vs Untrained groups) mixed design Multivariate Analysis of Covariance (MANCOVA) was used to analyse costs under dual attention conditions. The posttest data formed the dependent measures with Group as the fixed factor and the pretest data included as the covariates. The memory and RT costs performed under Free Recall and Cued Recall were analysed separately.

There were three memory costs each for Free Recall and Cued Recall tasks, namely, differences in memory performance under each of the three divided attention conditions, i.e., Divided Attention-Full Attention (DA-FA), Full Attention-Divided Attention (FA-DA), and Divided Attention-Divided Attention (DA-DA) and that in Full Attention-Full Attention (FA-FA). By similar subtractions, three RT costs (i.e., DA-FA, FA-DA, DA-DA minus FA-FA) were calculated for Free Recall and Cued Recall tasks. The memory cost and RT cost analyses are reported together to provide a comprehensive picture of the effect of video game training on both primary and secondary task costs.

Free Recall

The MANCOVA results showed that the main effect of training was statistically significant for memory costs associated with Free Recall tasks, Pillai's Trace = .381, F (3,18) = 3.696, p = .031. Levene's test of equality of error variance showed no violation of the homogeneity of variance assumption in the DA-FA – FA-FA, FA-DA – FA-FA, and DA-DA – DA-DA costs (all p's > .05). The covariate results (Appendix O1.1) were nonsignificant in all cases suggesting that the covariates were not used to adjust for group means.

The MANCOVA for the RT cost analysis showed that the main effect of training was statistically nonsignificant, Pillai's Trace = .263, F (4, 16) = 1.429, p > .05. Levene's test of equality of error variance showed no violation of the homogeneity of variance assumption in the DA-FA – FA-FA, FA-DA – FA-FA, and DA-DA – DA-DA costs (all p's > .05). The covariate results (Appendix O1.2) show nonsignificant results in all except five cases suggesting that the five significant covariates were used to adjust for group means while the others were not.

The follow-up ANCOVA for memory cost with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Full Attention at Retrieval (DA-FA) condition showed a statistically significant effect of training, F(1,20) = 6.193, MSE = 19.701, p = .022 (see Table 26) with the trained group showing a greater reduction in memory cost after training (M = 2.23; SD = 1.88) than the untrained group (M = 4.00; SD = 1.54). However, the follow-up ANCOVA for RT cost in the DA-FA condition showed the effect of training was statistically nonsignificant, F(1, 19) = .205, MSE = 365.630, p > .05 (see Table 28) showing that training did not impact on RT cost.

The follow-up ANCOVA for memory cost with group (trained vs. untrained) as the between-subjects variable in the Full Attention at Encoding - Divided Attention at Retrieval (FA-DA) condition showed a statistically significant effect of training, $F(1,20) = 6.866$, $MSE = 18.748$, $p = .016$ (see Table 26) with the trained group showing a greater reduction in memory cost after training ($M = 1.00$, $SD = 1.58$) compared to the untrained group ($M = 2.83$, $SD = 1.75$). In contrast, the follow-up ANCOVA for RT cost in the FA-DA condition did not show a statistically significant effect of training, $F(1,19) = .128$, $MSE = 1727.555$, $p > .05$ (see Table 28).

The follow-up ANCOVA for memory cost with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Divided Attention at Retrieval (DA-DA) condition showed a statistically nonsignificant effect of training, $F(1,20) = 1.323$, $MSE = 4.496$, $p > .05$ (see Table 26). Similarly, the follow-up ANCOVA for RT cost in the DA-DA condition also did not show a statistically significant effect of training at encoding, $F(1,19) = 3.036$, $MSE = 4231.677$, $p > .05$ or at retrieval, $F(1,19) = .003$, $MSE = 13.951$, $p > .05$ (see Table 28).

The means and standard deviations for memory and RT costs in all three follow-up ANCOVAs are presented in Tables 27 and 29 respectively.

Table 26

Follow-up ANCOVA results for memory costs associated with Free Recall tasks (N = 25) in the short-term training study

Attention condition	F	df	p
DAFA – FAFA	6.193	1, 20	.022*
FADA – FAFA	6.866	1, 20	.016*
DADA – FAFA	1.323	1, 20	> .05

* denotes significance at the .05 level

Note:
DAFA - FAFA (Memory performance of Divided attention at encoding, Full attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)
FA-DA - FAFA (Memory performance of Full attention at encoding, Divided attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)
DA-DA – FAFA (Memory performance of Divided attention at encoding and retrieval task minus memory performance with Full Attention at encoding and retrieval)

Table 27

Means and standard deviations for memory costs associated with Free Recall across pre- and posttests (N = 25) in the short-term training study

Attention condition	Trained Group				Untrained Group			
	Pretest		Posttest		Pretest		Posttest	
	M	SD	M	SD	M	SD	M	SD
DAFA– FAFA	2.69	2.06	2.23	1.88	2.42	2.27	4.00	1.54
FADA– FAFA	2.31	2.18	1.00	1.58	1.42	1.68	2.83	1.75
DADA– FAFA	3.00	2.38	3.00	1.73	3.17	2.21	3.75	2.05

Note:
DAFA - FAFA (Memory performance of Divided attention at encoding, Full attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)
FA-DA - FAFA (Memory performance of Full attention at encoding, Divided attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)
DA-DA – FAFA (Memory performance of Divided attention at encoding and retrieval task minus memory performance with Full Attention at encoding and retrieval)

Table 28

Follow-up ANCOVA results for Reaction Time costs associated with Free Recall in the short-term training study ($N = 25$)

Attention condition	F	df	p
DAFA -FAFA	.205	1, 19	> .05
FADA -FAFA	.128	1, 19	> .05
DADA (E)–FAFA	3.036	1, 19	> .05
DADA (R)-FAFA	.003	1,19	> .05

Note:

DAFA – FAFA (RT task performance with Divided attention at encoding, Full attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (RT task performance with Full attention at encoding, Divided attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (E) - FAFA (RT task performance at Encoding with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (R) - FAFA (RT task performance at Retrieval with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

Table 29

Means and standard deviations for Reaction Time costs associated with Free Recall (in milliseconds) across pre- and posttests in the short-term training study ($N = 25$)

Attention condition	Trained Group				UntrainedGroup			
	Pretest		Posttest		Pretest		Posttest	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
DAFA -FAFA	57.80	90.82	29.17	85.63	53.13	49.45	32.03	52.23
FADA -FAFA	286.92	230.74	167.39	214.39	135.54	120.61	94.98	90.68
DADA(E)–FAFA	133.90	114.23	43.67	88.29	70.25	39.84	24.07	68.17
DADA(R)-FAFA	262.22	234.94	115.15	79.10	30.81	101.17	70.29	88.69

Note:

DAFA – FAFA (RT task performance with Divided attention at encoding, Full attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (RT task performance with Full attention at encoding, Divided attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (E) - FAFA (RT task performance at Encoding with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (R) - FAFA (RT task performance at Retrieval with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

Cued Recall

The MANCOVA results for memory costs associated with Cued Recall tasks showed a statistically nonsignificant main effect of training, Pillai's Trace = .074, F (3,18) = .478, $p > .05$. Levene's test for equality of error variance showed there was no violation of the homogeneity of variance assumption in the FA-DA - FA-FA cost ($p > .05$), but this assumption was violated in the DA-FA - FA-FA and DA-DA - FA-FA costs ($p < .05$). However, since the main effect result was statistically nonsignificant, no further examination of this violation is required. The covariate results (Appendix P1.1) were nonsignificant in all cases suggesting that the covariates were not used to adjust for group means.

The MANCOVA for the RT cost analysis showed that the main effect of training was statistically nonsignificant, Pillai's Trace = .199, F (4, 16) = .996, $p >$ .05. Levene's test of equality of error variance showed no violation of the homogeneity of variance assumption in the DA-FA – FA-FA, FA-DA – FA-FA and DA-DA (R) - FA-FA costs ($p > .05$). However, this assumption was violated in the DA-DA (E) – FA-FA cost. However, since the main effect result was statistically nonsignificant, no further examination of this violation is required. The covariate results (Appendix P1.2) were nonsignificant results in all except four cases indicating that the four significant covariates were used to adjust for group means while the others were not.

The follow-up ANCOVA for memory cost with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Full Attention at Retrieval (DA-FA) condition showed a statistically nonsignificant effect of training, $F(1,20) = 1.183$, $MSE = 8.466$, $p > .05$ (see Table 30). *Similarly, the follow-up ANCOVA for RT cost in the DA-FA condition also showed a statistically nonsignificant effect of training, $F(1, 19) = 1.252$, $MSE = 4259.181$, $p > .05$ (see Table 32).

The follow-up ANCOVA for memory cost with group (trained vs. untrained) as the between-subjects variable in the Full Attention at Encoding - Divided Attention at Retrieval (FA-DA) condition showed a statistically nonsignificant effect of training, $F(1,20) = 1.120$, $MSE = 8.639$, $p > .05$ (see Table 30). Likewise, the follow-up ANCOVA for RT cost in the FA-DA condition also did not show a statistically significant effect of training, $F(1,19) = .859$, $MSE = 4475.240$, $p > .05$ (see Table 32).

The follow-up ANCOVA for memory cost with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Divided Attention at Retrieval (DA-DA) condition showed a statistically non-significant effect of training, $F(1,20) = .264$, $MSE = 2.321$, $p > .05$ (see Table 30). Similarly, the follow-up ANCOVA for RT cost in the DA-DA condition also did not show a statistically significant effect of training at encoding, $F(1,19) = 3.092$, $MSE = 14154.386$, $p > .05$ or at retrieval, $F(1,19) = 3.482$, $MSE = 50359.621$, $p > .05$ (see Table 32).

The means and standard deviations for memory and RT costs in all three follow-up ANCOVAs are presented in Tables 31 and 33 respectively.

Table 30

Follow-up ANCOVA results for memory costs associated with Cued Recall tasks in the short-term training study ($N = 25$)

Attention condition	F	df	p
DAFA – FAFA	1.183	1, 20	> .05
FADA – FAFA	1.120	1, 20	> .05
DADA – FAFA	.264	1, 20	> .05

Note:
DAFA - FAFA (Memory performance of Divided attention at encoding, Full attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)
FA-DA - FAFA (Memory performance of Full attention at encoding, Divided attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)
DA-DA – FAFA (Memory performance of Divided attention at encoding and retrieval task minus memory performance with Full Attention at encoding and retrieval)

Table 31

Means and standard deviations for memory costs associated with Cued Recall across pre- and posttests in the short-term training study ($N = 25$)

Attention	Trained Group				Untrained Group			
condition	Pretest		Posttest		Pretest		Posttest	
	M	SD	M	SD	M	SD	M	SD
DAFA– FAFA	3.62	3.01	4.00	1.91	2.67	2.23	2.33	3.11
FADA– FAFA	1.69	2.06	1.92	2.66	0.75	2.83	0.42	2.91
DADA– FAFA	3.92	2.56	3.69	2.53	2.17	2.29	2.58	3.29

Note:
DAFA - FAFA (Memory performance of Divided attention at encoding, Full attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)
FA-DA - FAFA (Memory performance of Full attention at encoding, Divided attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)
DA-DA – FAFA (Memory performance of Divided attention at encoding and retrieval task minus memory performance with Full Attention at encoding and retrieval)

Table 32

Follow-up ANCOVA results for Reaction Time costs associated with Cued Recall in the short-term training study ($N = 25$)

Attention condition	F	df	p
DAFA -FAFA	1.252	1, 19	> .05
FADA -FAFA	.859	1, 19	> .05
DADA (E)–FAFA	3.092	1, 19	> .05
DADA (R)-FAFA	3.482	1,19	> .05

Note:

DAFA – FAFA	(RT task performance with Divided attention at encoding, Full attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)
FA-DA - FAFA	(RT task performance with Full attention at encoding, Divided attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)
DA-DA (E) - FAFA	(RT task performance at Encoding with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)
DA-DA (R) - FAFA	(RT task performance at Retrieval with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

Table 33

Means and standard deviations for Reaction Time costs (in milliseconds) associated with Cued Recall across pre- and posttests in the short-term training study ($N = 25$)

Attention condition	Trained Group				Untrained Group			
	Pretest		Posttest		Pretest		Posttest	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
DAFA -FAFA	107.41	111.06	60.21	123.71	58.51	70.86	55.80	76.46
FADA -FAFA	270.03	154.27	143.78	99.96	150.97	181.81	124.78	94.06
DADA(E)–FAFA	99.43	119.51	28.45	69.12	49.87	62.35	61.74	91.89
DADA(R)-FAFA	274.05	212.21	131.71	81.02	161.86	148.62	157.20	233.08

Note:

DAFA – FAFA (RT task performance with Divided attention at encoding, Full attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (RT task performance with Full attention at encoding, Divided attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (E) - FAFA (RT task performance at Encoding with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (R) - FAFA (RT task performance at Retrieval with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

Summary of Effect of Short-term Video Game Training on Memory and Reaction Time costs

The results demonstrate that short-term video game training has the potential to reduce costs associated with memory recall when the tasks are presented in a dual-attention condition. This is displayed in the Free Recall task analysis wherein memory costs in two of the three divided attention conditions have been significantly reduced. However, the same is not seen in the Cued Recall results. The results also demonstrate that short-term video game training is not sufficient to reduce costs associated with a secondary task as illustrated by the lack of a training effect on Reaction Time costs across Free Recall and Cued Recall tasks. Overall, the results provide partial support to Hypothesis 2 as they indicate that video game training can affect memory processes by reducing costs associated with their performance in a dual-attention condition.

Analysis to show the effect of video game training on memory processes

Study 2

Hypothesis 2

The following section presents the results of the analysis that examined the second hypothesis, i.e., whether video game training affects memory processes such that: (a) when attention is divided at encoding, memory costs will be reduced along with concurrent secondary task costs, (b) when attention is divided at retrieval, memory costs will be reduced along with concurrent secondary task costs, and (c) with attention divided at both encoding and retrieval, there will be a decrease in memory costs and concurrent secondary task costs.

The data of the long-term video game training group was analysed in the same manner as in Study 1.

Free Recall

The MANCOVA results showed that the main effect of training was statistically nonsignificant for memory costs associated with Free Recall tasks, Pillai's Trace = .201, $F\,(3,18) = 1.511, p > .05$. Levene's test of equality of error variance showed no violation of the homogeneity of variance assumption for the DA-FA – FA-FA, FA-DA – FA-FA, and DA-DA – DA-DA memory costs (all *p's* > .05). The covariate results (Appendix Q1.1) were nonsignificant in all cases suggesting that the covariates were not used to adjust for group means.

The MANCOVA for the RT cost analysis showed that the main effect of training was statistically nonsignificant, Pillai's Trace = .379, $F\,(4, 15) = 2.285, p >$

.05. Levene's test of equality of error variance showed no violation of the homogeneity of variance assumption in all four RT costs i.e., DA-FA – FA-FA, FA-DA – FA-FA, DA-DA (E) – FA-FA, and DA-DA (R) - FA-FA (all *p's* > .05). The covariate results (Appendix Q1.2) were nonsignificant in all except three cases indicating that the three significant covariates were used to adjust for group means while the others were not.

The follow-up ANCOVA for memory cost with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Full Attention at Retrieval (DA-FA) condition showed a statistically nonsignificant effect of training, $F(1,20) = 1.258$, $MSE = 11.698$, $p > .05$ (see Table 34). Similarly, the follow-up ANCOVA for RT cost in the DA-FA condition also showed a nonsignificant effect of training, $F(1, 18) = 1.370$, $MSE = 4282.937$, $p > .05$ (see Table 36).

The follow-up ANCOVA for memory cost with group (trained vs. untrained) as the between-subjects variable in the Full Attention at Encoding - Divided Attention at Retrieval (FA-DA) condition showed a statistically significant effect of training, $F(1,20) = 4.410$, $MSE = 22.490$, $p = .049$ (see Table 34) with the trained group showing a greater reduction in cost after training ($M = 0.42$, $SD = 2.47$) compared to the untrained group ($M = 2.54$, $SD = 1.85$). On the other hand, the follow-up ANCOVA for RT cost in the FA-DA condition did not show a statistically significant effect of training, $F(1,18) = 1.430$, $MSE = 13834.036$, $p > .05$ (see Table 36).

The follow-up ANCOVA for memory cost with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Divided Attention at Retrieval (DA-DA) condition showed a statistically nonsignificant effect of training, $F(1,20) = 1.591$, $MSE = 9.212$, $p > .05$ (see Table 34). The follow-up

ANCOVA for RT cost in the DA-DA condition also did not show a statistically significant effect of training at encoding, $F(1,18) = .296$, $MSE = 1162.829$, $p > .05$ or at retrieval, $F(1,18) = .215$, $MSE = 3861.150$, $p > .05$ (see Table 36).

The means and standard deviations for memory and RT costs for all the three follow-up ANCOVAs are presented in Tables 35 and Table 36A respectively.

Table 34

Follow-up ANCOVA results for memory costs associated with Free Recall tasks in the long-term training study ($N = 25$)

Attention condition	F	df	p
DAFA – FAFA	1.258	1, 20	> .05
FADA – FAFA	4.410	1, 20	.049*
DADA – FAFA	1.591	1, 20	> .05

* denotes significance at the .05 level

Note:

DAFA - FAFA (Memory performance of Divided attention at encoding, Full attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (Memory performance of Full attention at encoding, Divided attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

DA-DA – FAFA (Memory performance of Divided attention at encoding and retrieval task minus memory performance with Full Attention at encoding and retrieval)

Table 35

Means and standard deviations for memory costs associated with Free Recall across pre- and posttests in the long-term training study ($N = 25$)

Attention condition	Trained Group				Untrained Group			
	Pretest		Posttest		Pretest		Posttest	
	M	SD	M	SD	M	SD	M	SD
DAFA– FAFA	3.00	2.66	2.67	2.84	2.23	2.92	3.85	3.26
FADA– FAFA	1.25	2.09	0.42	2.47	2.00	3.67	2.54	1.85
DADA– FAFA	2.50	1.78	2.58	2.97	2.38	3.31	3.85	2.08

Note:

DAFA - FAFA (Memory performance of Divided attention at encoding, Full attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (Memory performance of Full attention at encoding, Divided attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

DA-DA – FAFA (Memory performance of Divided attention at encoding and retrieval task minus memory performance with Full Attention at encoding and retrieval)

Table 36

Follow-up ANCOVA results for Reaction Time costs associated with Free Recall in the long-term training study ($N = 25$)

Attention condition	F	df	p
DAFA -FAFA	1.370	1, 18	> .05
FADA -FAFA	1.430	1, 18	> .05
DADA (E)–FAFA	.296	1, 18	> .05
DADA (R)-FAFA	.215	1,18	> .05

Note:

DAFA – FAFA	(RT task performance with Divided attention at encoding, Full attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)
FA-DA - FAFA	(RT task performance with Full attention at encoding, Divided attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)
DA-DA (E) - FAFA	(RT task performance at Encoding with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)
DA-DA (R) - FAFA	(RT task performance at Retrieval with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

Table 36A

Means and standard deviations for Reaction Time costs associated with Free Recall (in milliseconds) across pre- and posttests in the long-term training study ($N = 25$)

Attention condition	Trained Group				Untrained Group			
	Pretest		Posttest		Pretest		Posttest	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
DAFA -FAFA	58.10	62.30	30.81	59.69	104.82	96.15	40.36	86.71
FADA -FAFA	309.79	450.95	68.86	77.22	242.84	261.73	202.21	206.64
DADA(E)-FAFA	53.31	108.01	29.23	60.78	125.97	117.59	94.25	113.64
DADA(R)-FAFA	130.88	162.65	90.68	120.85	239.20	209.65	170.58	244.52

Note:

DAFA – FAFA (RT task performance with Divided attention at encoding, Full attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (RT task performance with Full attention at encoding, Divided attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (E) - FAFA (RT task performance at Encoding with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (R) - FAFA (RT task performance at Retrieval with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

Cued Recall

The MANCOVA results for memory costs associated with Cued Recall tasks showed the main effect of training to lie just above the alpha level, Pillai's Trace = .330, F (3,18) = 2.950, p = .06. Hence, the result is considered statistically non-significant. Levene's test for equality of error variance showed no violation of the homogeneity of variance assumption in all three divided attention conditions, i.e., in the DA-FA - FA-FA, FA-DA - FA-FA, and DA-DA - FA-FA memory costs. The covariate results (Appendix R1.1) were nonsignificant in all except one case suggesting that the one significant covariate was used to adjust for group means while the others were not.

The MANCOVA for the RT cost analysis showed that the main effect of training was statistically nonsignificant, Pillai's Trace = .228, F (4, 15) = 1.109, p > .05. Levene's test of equality of error variance showed no violation of the homogeneity of variance assumption in DA-FA – FA-FA, DA-DA (E) - FA-FA, and DA-DA (R) – FA-FA costs. However, this assumption was violated in the FA-DA - FA-FA cost. Since the follow-up ANCOVA analysis did not reveal a significant effect of training, no caution needs to be exercised in the interpretation of this result. The covariate results (Appendix R1.2) were nonsignificant results in all except five cases indicating that the five significant covariates were used to adjust for group means while the others were not.

The follow-up ANCOVA for memory cost with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Full Attention at Retrieval (DA-FA) condition showed a statistically significant effect of training, F(1,20) = 7.271, MSE = 35.165, p = .014 (see Table 37) with the trained group showed a significantly reduced memory cost at posttest (M = 1.00, SD = 1.71) compared to the untrained group ($M = 3.08$, $SD = 2.06$). However, the follow-up ANCOVA for RT cost in the DA-FA condition showed a statistically nonsignificant effect of training, $F(1, 18) = .019$, $MSE = 74.063$, $p > .05$ (see Table 39).

The follow-up ANCOVA for memory cost with group (trained vs. untrained) as the between-subjects variable in the Full Attention at Encoding - Divided Attention at Retrieval (FA-DA) condition showed a statistically significant effect of training, $F(1,20) = 6.797$, $MSE = 23.130$, $p = .017$ (see Table 37) with the trained group showing a substantial reduction in memory cost after training ($M = 1.00$, $SD = 1.71$) compared to the untrained group ($M = 3.08$, $SD = 2.06$). In contrast, the follow-up ANCOVA for RT cost in the FA-DA condition did not show a statistically significant effect of training, $F(1,18) = .915$, $MSE = 9189.141$, $p > .05$ (see Table 39).

The follow-up ANCOVA for memory cost with group (trained vs. untrained) as the between-subjects variable in the Divided Attention at Encoding - Divided Attention at Retrieval (DA-DA) condition showed a statistically significant effect of training, $F(1,20) = 5.806$, $MSE = 19.968$, $p = .026$ (see Table 37) with the trained group showing a greater reduction in memory cost after training ($M = 2.25$, $SD = 1.91$) compared to the untrained group ($M = 4.38$, $SD = 2.40$) (see Table 38). However, the follow-up ANCOVA for RT costs in the DA-DA condition did not show a statistically significant effect of training at encoding, $F(1,18) = .692$, $MSE = 2724.241$, $p > .05$ or at retrieval, $F(1,18) = .448$, $MSE = 2911.755$, $p > .05$ (see Table 39).

The means and standard deviations for memory and RT costs for the three follow-up ANCOVAs are presented in Tables 38 and 40 respectively.

Table 37

Follow-up ANCOVA results for memory costs associated with Cued Recall tasks in the long-term training study ($N = 25$)

Attention condition	F	df	p
DAFA – FAFA	7.271	1, 20	.014**
FADA – FAFA	6.797	1, 20	.017**
DADA – FAFA	5.806	1, 20	.026*

**denotes significance at the .01 level; * denotes significance at the .05 level

Note:

DAFA - FAFA (Memory performance of Divided attention at encoding, Full attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (Memory performance of Full attention at encoding, Divided attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

DA-DA – FAFA (Memory performance of Divided attention at encoding and retrieval task minus memory performance with Full Attention at encoding and retrieval)

Table 38

Means and standard deviations for memory costs associated with Cued Recall across pre- and posttests in the long-term training study ($N = 25$)

Attention	Trained Group				Untrained Group			
condition	Pretest		Posttest		Pretest		Posttest	
	M	SD	M	SD	M	SD	M	SD
DAFA– FAFA	2.68	2.99	1.75	2.56	3.15	2.15	4.54	2.47
FADA– FAFA	0.75	2.60	1.00	1.71	1.54	1.98	3.08	2.06
DADA– FAFA	2.25	3.31	2.25	1.91	2.77	2.55	4.38	2.40

Note:

DAFA - FAFA (Memory performance of Divided attention at encoding, Full attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (Memory performance of Full attention at encoding, Divided attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

DA-DA – FAFA (Memory performance of Divided attention at encoding and retrieval task minus memory performance with Full Attention at encoding and retrieval)

Table 39

Follow-up ANCOVA results for Reaction Time costs associated with Cued Recall in the long-term training study ($N = 25$)

Attention condition	*F*	df	*p*
DAFA -FAFA	.019	1, 18	> .05
FADA -FAFA	.915	1, 18	> .05
DADA (E)–FAFA	.692	1, 18	> .05
DADA (R)-FAFA	.448	1,18	> .05

Note:

DAFA – FAFA	(RT task performance with Divided attention at encoding, Full attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)
FA-DA - FAFA	(RT task performance with Full attention at encoding, Divided attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)
DA-DA (E) - FAFA	(RT task performance at Encoding with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)
DA-DA (R) - FAFA	(RT task performance at Retrieval with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

Table 40

Means and standard deviations for Reaction Time costs associated with Cued Recall (in milliseconds) across pre- and posttests in the long-term training study ($N = 25$)

Attention condition	Trained Group				Untrained Group			
	Pretest		Posttest		Pretest		Posttest	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
DAFA -FAFA	77.36	114.96	29.34	67.01	122.68	113.70	77.23	87.88
FADA -FAFA	168.11	169.39	116.39	130.18	291.52	316.73	184.72	246.31
DADA(E)–FAFA	95.85	187.21	11.75	66.41	150.75	120.79	90.29	130.87
DADA(R)-FAFA	225.46	282.68	83.26	94.06	268.65	254.32	200.69	240.03

Note:

DAFA – FAFA (RT task performance with Divided attention at encoding, Full attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (RT task performance with Full attention at encoding, Divided attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (E) - FAFA (RT task performance at Encoding with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (R) - FAFA (RT task performance at Retrieval with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

Summary of Effect of Long-term video game training on Memory and Reaction Time costs

The results of the long-term video game training demonstrate that the training medium can significantly reduce costs associated with memory recall when the tasks are presented in a dual-attention condition. This is displayed in the Free Recall and Cued Recall task analysis wherein memory costs in most of the divided attention conditions have been significantly reduced. There is an added effect of training seen in the results here compared to the short-term training results. While no effect of training on memory costs was seen in the Cued Recall tasks in Study 1, memory costs associated with all three divided attention conditions have been significantly reduced in Study 2.

The results further demonstrate that even long-term video game training is not sufficient to reduce costs associated with secondary tasks. This is illustrated by the lack of a training effect on Reaction Time costs across Free Recall and Cued Recall tasks. Consequently, the results provide partial support to Hypothesis 2 as they indicate that video game training could affect the memory processes of encoding and retrieval by reducing costs associated with their performance in a dual-attention condition.

Analysis to show the Asymmetrical Effect of Video Game Training and Divided Attention on Memory Processes

Study 1

Hypothesis 3

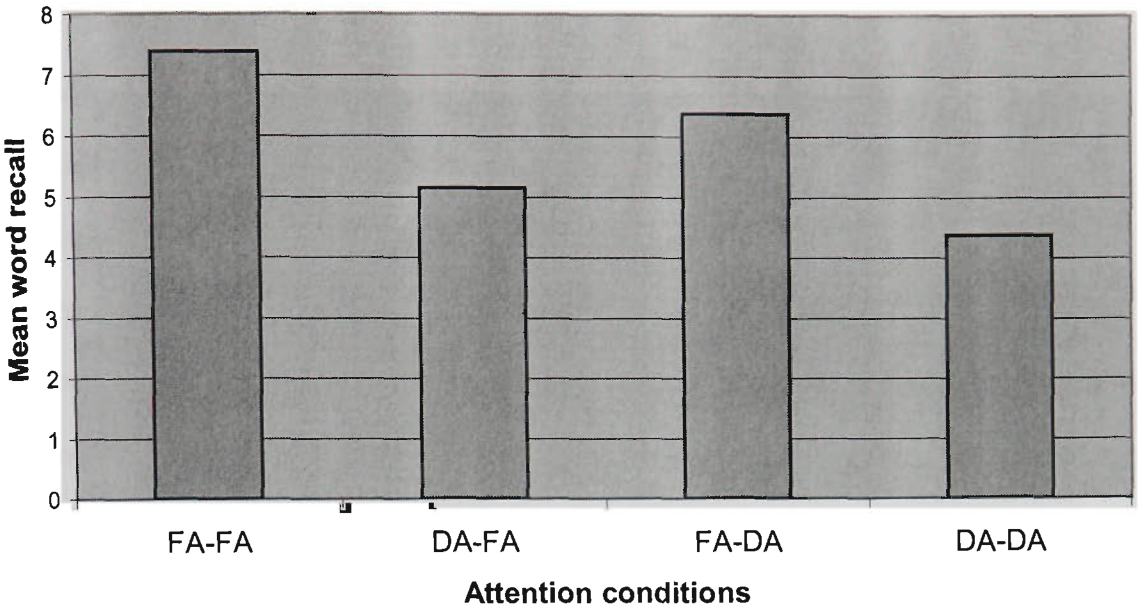
The following section presents the analysis that was conducted to determine whether video game training and divided attention affect encoding and retrieval processes differentially such that: (a) when attention is divided at encoding, memory performance will drop substantially but the concurrent secondary task performance will not, (b) division of attention at retrieval will result in a slight drop in memory but will lead to a large increase in the concurrent secondary task performance, and (c) division of attention at both encoding and retrieval will result in a substantial decrease in memory performance and the concurrent secondary task performance.

Full Attention versus Divided Attention

Free Recall

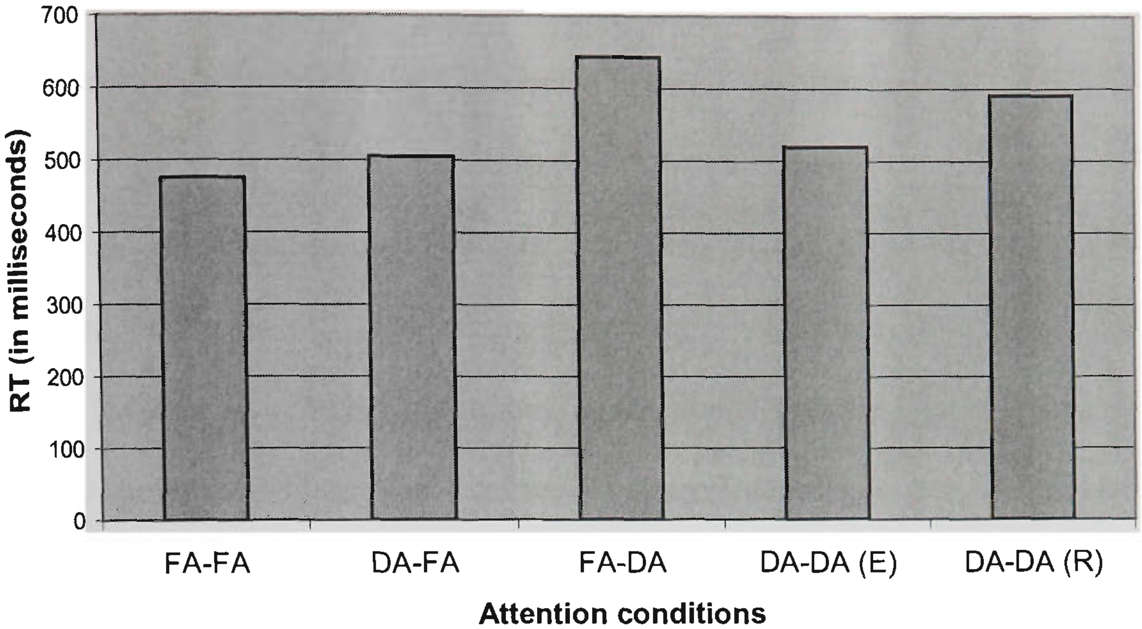
Paired samples-t-tests were conducted to assess the differential effect of video game training and divided attention on word recall and RT performance between full attention and divided attention conditions. Only posttest data of the trained group was considered for this analysis. The maximum number of words that could be recalled was 12. Figure 18 shows the difference in word recall between the full attention and divided attention conditions and figure 19 shows the difference in RT performance between the full attention and divided attention conditions. In line with previous studies, the t-test revealed that divided attention at encoding reduces recall substantially (5.15 (SD = 1.86) compared to 7.38[5] (SD = 1.61) words, t (12) = 4.284, p = .001), but has a statistically nonsignificant effect on RT performance (M = 504.84 ms, SD = 105.98 ms vs. M = 475.67 ms, SD = 72.02 ms), t (12) = 1.228, $p > .05$. Conversely, divided attention at retrieval is associated with a smaller, statistically significant reduction in recall (M = 6.38, SD = 1.93 vs. M = 7.38, SD = 1.61) words, t (12) = 2.280, p = .042) but with a larger, statistically significant increase in RT (M = 643.07 ms, SD = 236.23 ms vs. M = 475.67 ms, SD = 72.02 ms), t (12) = 2.815, p = .016. When attention was divided at both encoding and retrieval, recall performance was similar to levels found when attention was divided at encoding only. Word recall was reduced substantially (M = 4.38, SD = 1.85 vs. M = 7.38, SD = 1.61) words, t (12) = 6.245, p = .001. Likewise, RT performance at encoding was no different to the level when attention was divided at encoding (M = 519.34 ms, SD = 114.67 ms vs. M = 475.67 ms, SD = 72.02 ms), t (12) = 1.783, $p > .05$ and RT performance at retrieval was similar to the level when attention was divided at retrieval (M = 590.83 ms, SD = 107.65 ms vs. M = 475.57 ms, SD = 72.02 ms), t (12) = 5.249, p = .001.

[5] Note: All comparisons of the Mean are made between performance at divided attention versus performance at full attention conditions.



Note:
FA-FA (Full attention at encoding; full attention at retrieval)
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Figure 18. Difference in word recall between full attention and divided attention conditions in the Free Recall tasks in the trained short-term training group ($N = 13$).



Note:

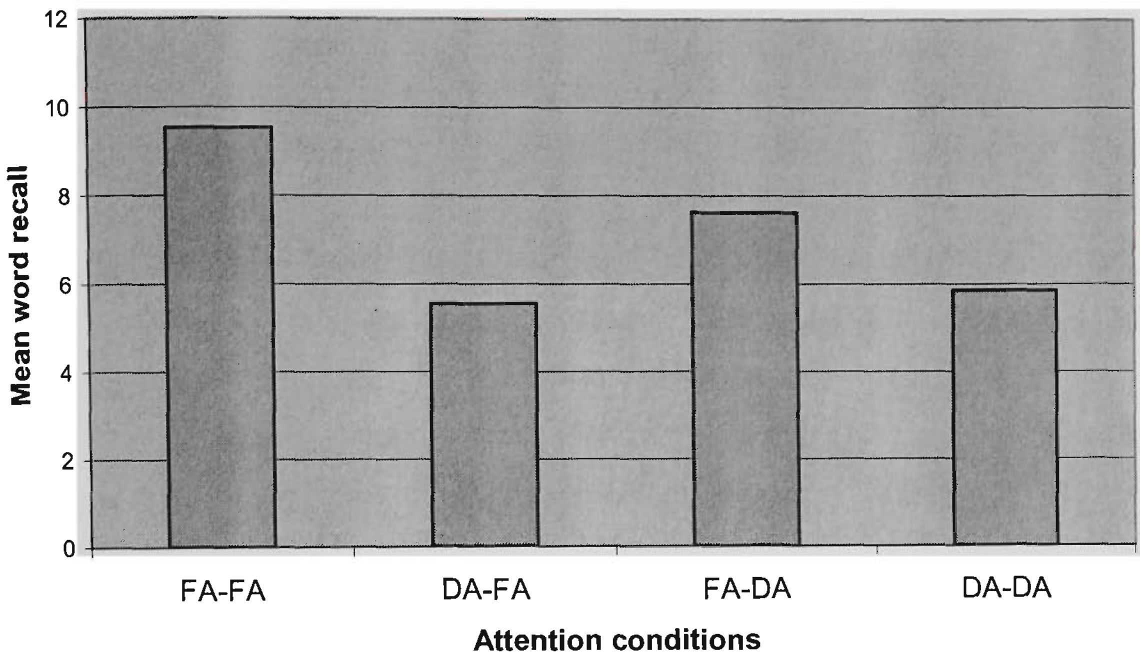
FA-FA	(Full attention at encoding; full attention at retrieval)
DA-FA	(Divided attention at encoding; full attention at retrieval)
FA-DA	(Full attention at encoding; divided attention at retrieval)
DA-DA (E)	(Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R)	(Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Figure 19. Difference in RT performance (in milliseconds) between full attention and divided attention conditions in the Free Recall tasks in the trained short-term training group ($N = 13$).

Cued Recall

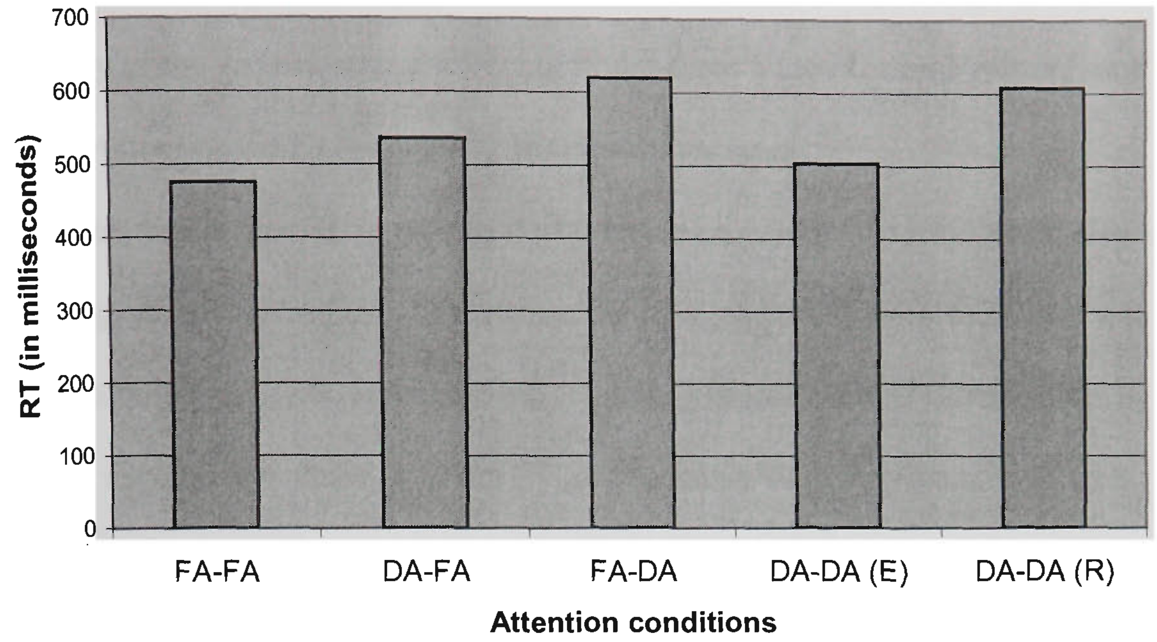
Paired samples-t-tests were conducted to assess the differential effect of video game training and divided attention on word recall and RT performance between full attention and divided attention conditions. Only posttest data of the trained group was considered for this analysis. The maximum number of words that could be recalled was 12. The analysis reflects the pattern of results found with the Free Recall data. Figure 20 shows the difference in word recall between the full attention and divided attention conditions and Figure 21 shows the difference in RT performance between the full attention and divided attention conditions.

The paired sample t-test revealed that divided attention at encoding reduces recall substantially compared to full attention performance ($M = 5.54$, $SD = 2.54$ vs. $M = 9.54$, $SD = 1.98$ words), $t\,(12) = 7.532, p = .001$, but has a smaller statistically nonsignificant effect on RT performance ($M = 535.88$ ms, $SD = 137.62$ ms vs. $M = 475.67$ ms, $SD = 72.02$ ms), $t\,(12) = 1.755, p > .05$. Conversely, divided attention at retrieval is associated with a smaller but statistically significant reduction in recall ($M = 7.62$, $SD = 2.33$ vs. $M = 9.54$, $SD = 1.98$ words), $t\,(12) = 2.606, p = .023$), but with a larger statistically significant increase in RT ($M = 619.46$ ms, $SD = 110.94$ ms vs. $M = 475.67$ ms, $SD = 72.02$ ms), $t\,(12) = 5.186, p = .001$. When attention was divided at both encoding and retrieval, recall performance was no different to levels found when attention was divided at encoding only. Word recall was reduced substantially ($M = 5.85$, $SD = 2.27$ vs. $M = 9.54$, $SD = 1.98$), $t\,(12) = 6.245, p = .001$. Likewise, RT performance at encoding was no different to the level when attention was divided at encoding ($M = 504.12$ ms, $SD = 92.68$ ms vs. $M = 475.67$ ms, $SD = 72.02$ ms), $t\,(12) = 1.484, p > .05$. RT performance at retrieval was also no different to the level when attention was divided at retrieval only (M = 607.38 ms, SD = 135.00 ms vs. M = 475.57 ms, SD = 72.02 ms), $t\,(12) = 5.861, p = .001$.



Note:
FA-FA (Full attention at encoding; full attention at retrieval)
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Figure 20. Difference in word recall between full attention and divided attention conditions in the Cued Recall tasks in the trained short-term training group (N = 13).



Note:

FA-FA	(Full attention at encoding; full attention at retrieval)
DA-FA	(Divided attention at encoding; full attention at retrieval)
FA-DA	(Full attention at encoding; divided attention at retrieval)
DA-DA (E)	Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R)	(Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Figure 21. Difference in RT performance (in milliseconds) between full attention and divided attention conditions in the Cued Recall tasks in the trained short-term training group ($N = 13$).

Summary of the Asymmetrical Effect of Short-term Video Game Training and Divided Attention on Encoding and Retrieval Processes

The results provide support to the hypothesis regarding the differential effects of training and division of attention on encoding and retrieval processes. There was a substantial effect of divided attention at encoding (in both Free and Cued Recall tasks) on recall performance, whereas RT (or secondary task) performance was not affected greatly. On the other hand, divided attention at retrieval showed no substantial decrement in memory performance (on both Free and Cued Recall tasks) compared to the Full Attention condition, however, RT performance showed a significant decline. When attention was divided at both encoding and retrieval, recall performance was similar to the level of divided attention only at encoding. Similarly, the RT performance at encoding was in line with RT performance when attention was divided only at encoding and RT performance at retrieval was comparable to RT performance when attention was divided only at retrieval. These findings suggest that short-term video game training cannot alter the differential effect of divided attention on encoding and retrieval processes.

Analysis to show the Asymmetrical effect of video game training and divided attention on memory processes

Study 2

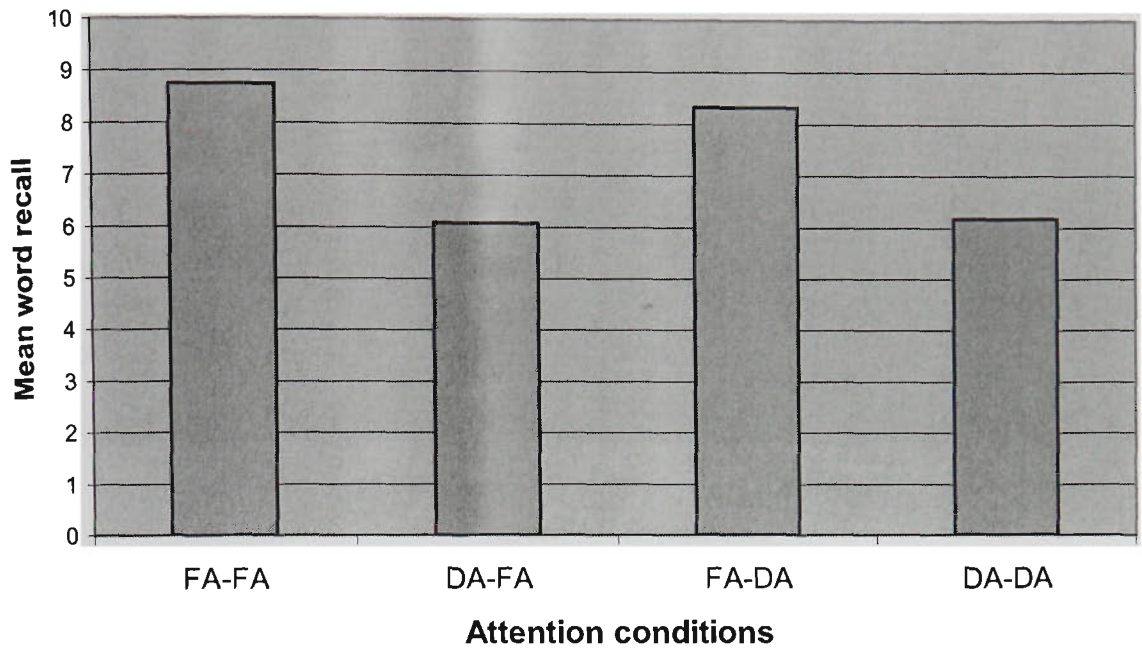
Hypothesis 3

The following section presents the analysis that was conducted to determine whether video game training and divided attention affect encoding and retrieval processes differentially such that: (a) when attention is divided at encoding, memory performance will drop substantially but the concurrent secondary task performance will not, (b) division of attention at retrieval will result in a slight drop in memory but will lead to a large increase in the concurrent secondary task performance, and (c) division of attention at both encoding and retrieval will result in a substantial decrease in memory performance and the concurrent secondary task performance.

Full Attention versus Divided Attention

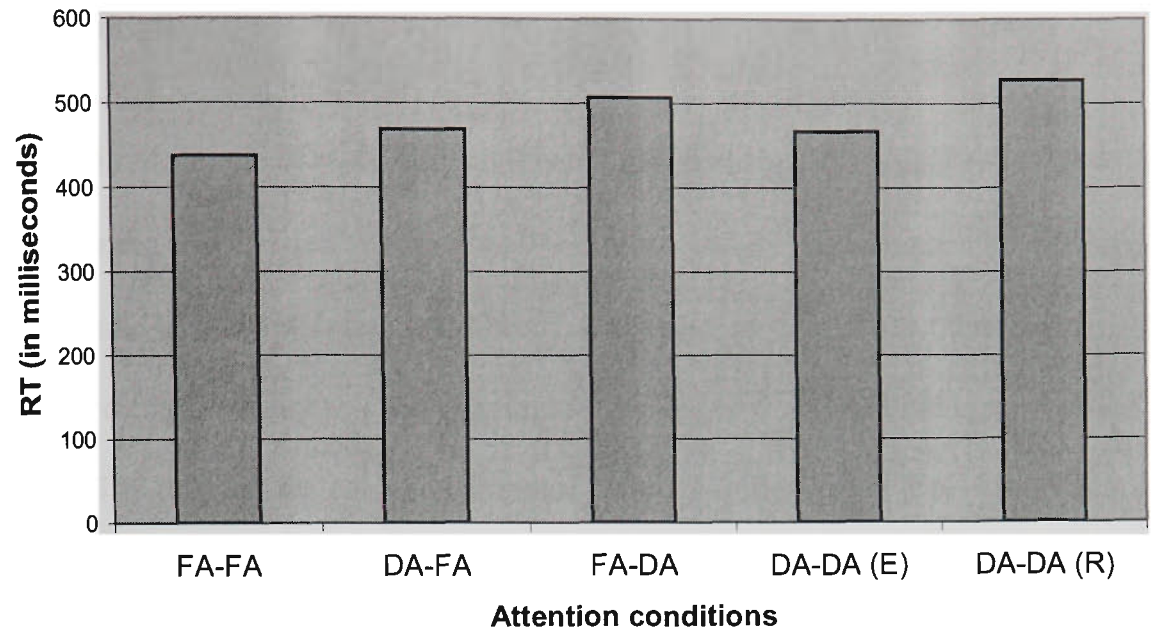
Free Recall

Paired samples-t-tests were conducted to assess the differential effect of video game training and divided attention on word recall and RT performance between full attention and divided attention conditions. Only posttest data of the trained group was considered for this analysis. The maximum number of words that could be recalled was 12. Figure 22 shows the difference in word recall between the full attention and divided attention conditions and Figure 23 shows the difference in RT performance between the full attention and divided attention conditions. The pattern of results is the same as in Study 1. Thus, the t-test revealed that divided attention at encoding reduces recall substantially ($M = 6.08$, $SD = 2.71$ vs. $M = 8.75$, $SD = 1.36$ words), t (11) = 3.254, $p = .008$, but has a smaller statistically nonsignificant effect on RT performance ($M = 468.29$ ms, $SD = 64.03$ ms vs. $M = 437.48$ ms, $SD = 40.57$ ms), t (11) = 1.788, $p > .05$. Conversely, divided attention at did not significantly reduce recall ($M = 8.33$, $SD = 2.57$ vs. $M = 8.75$, $SD = 1.36$ words), t (11) = .585, $p > .05$, but increased RT significantly ($M = 506.35$ ms, $SD = 83.78$ ms vs. $M = 437.48$ ms, $SD = 40.57$ ms), t (11) = 3.089, $p = .010$. When attention was divided at both encoding and retrieval, recall performance was similar to levels found when attention was divided at encoding only. Word recall reduced substantially ($M = 6.17$, $SD = 2.79$ vs. $M = 8.75$, $SD = 1.36$ words), t (11) = 3.015, $p = .012$. Likewise, RT performance at encoding was no different to the level when attention was divided at encoding ($M = 466.71$ ms, $SD = 70.72$ ms vs. $M = 437.48$ ms, $SD = 40.57$ ms), t (11) = 1.666, $p > .05$. RT performance at retrieval was also no different to the level when attention was divided at retrieval ($M = 528.16$ ms, $SD = 123.29$ ms vs. $M = 437.48$ ms, $SD = 40.57$ ms), t (11) = 2.599, $p = .025$.



Note:
FA-FA (Full attention at encoding; full attention at retrieval)
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Figure 22. Difference in word recall between full attention and divided attention conditions in the Free Recall tasks in the trained long-term training group ($N = 12$).



Note:

FA-FA	(Full attention at encoding; full attention at retrieval)
DA-FA	(Divided attention at encoding; full attention at retrieval)
FA-DA	(Full attention at encoding; divided attention at retrieval)
DA-DA (E)	(Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R)	(Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

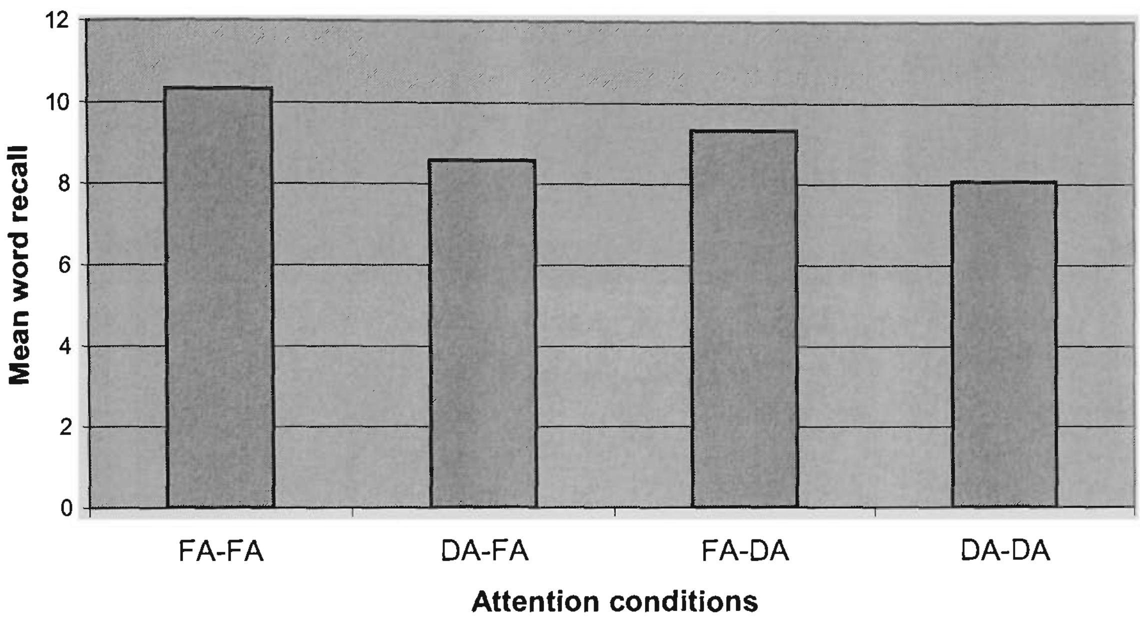
Figure 23. Difference in RT performance (in milliseconds) between full attention and divided attention conditions in the Free Recall tasks in the trained long -term training group (N = 12).

Cued Recall

Paired samples-t-tests were conducted to assess the differential effect of video game training and divided attention on word recall and RT performance between full attention and divided attention conditions. Only posttest data of the trained group was considered for this analysis. The maximum number of words that could be recalled was 12. The analysis reflects the pattern of results found with the Free Recall data in Study 2 and with the Cued Recall data of Study 1. Figure 24 shows the difference in word recall between the full attention and divided attention conditions and Figure 25 shows the difference in RT performance between the full attention and divided attention conditions.

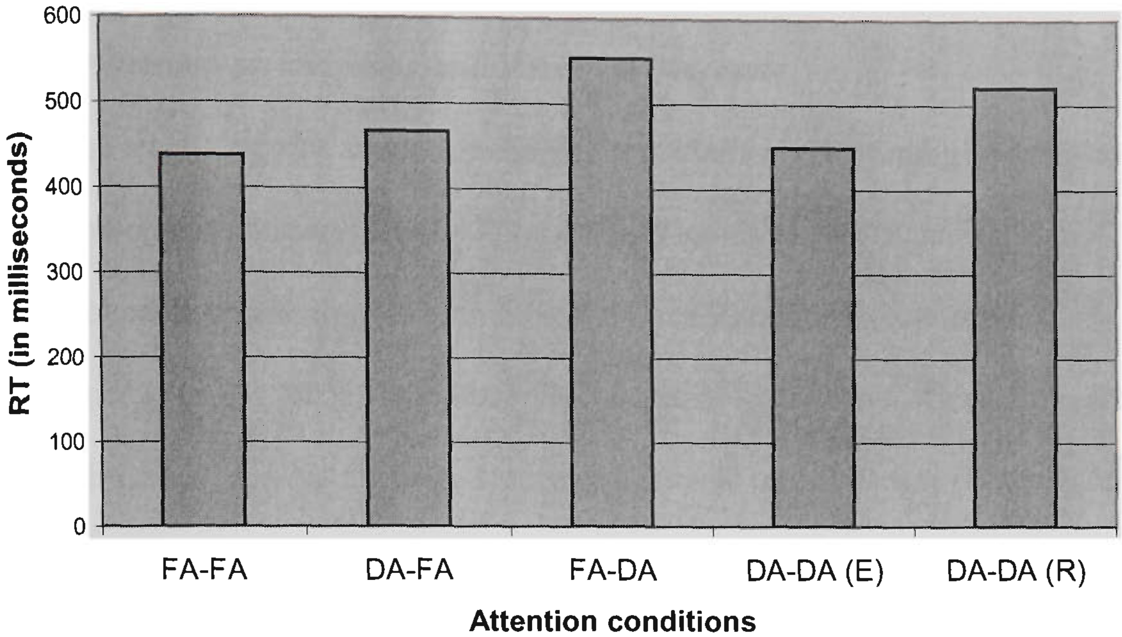
The t-test revealed that divided attention at encoding reduces recall substantially compared to full attention performance ($M = 8.58$, $SD = 2.31$ vs. $M = 10.33$, $SD = 1.07$ words), $t\,(11) = 2.365$, $p = .037$, but has a smaller statistically nonsignificant effect on RT performance ($M = 466.82$ ms, $SD = 65.13$ ms vs. $M = 437.48$ ms, $SD = 40.57$ ms), $t\,(11) = 1.516$, $p > .05$. Conversely, divided attention at retrieval is associated with a smaller, statistically nonsignificant reduction in recall ($M = 9.33$, $SD = 2.15$ vs. $M = 10.33$, $SD = 1.07$ words), $t\,(11) = 2.031$, $p > .05$, but with a larger, statistically significant increase in RT ($M = 553.88$ ms, $SD = 145.85$ ms vs. $M = 437.48$ ms, $SD = 40.57$ ms), $t\,(11) = 3.017$, $p = .010$. When attention was divided at both encoding and retrieval, recall performance was similar to levels found when attention was divided at encoding only. Word recall reduced substantially ($M = 8.08$, $SD = 2.15$ vs. $M = 10.33$, $SD = 1.07$ words), $t\,(11) = 4.075$, $p = .002$. Likewise, RT performance at encoding was no different to the level when attention was divided at encoding ($M = 449.23$ ms, $SD = 63.03$ ms vs. $M = 437.48$ ms, $SD = 40.57$ ms), $t\,(11)$

$= .613, p > .05$. RT performance at retrieval was also no different to the level when attention was divided at retrieval ($M = 520.74$ ms, $SD = 104.65$ ms vs. $M = 437.48$ ms, $SD = 40.57$ ms), $t\,(11) = 3.066, p = .011$.



Note:
FA-FA (Full attention at encoding; full attention at retrieval)
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

Figure 24. Difference in word recall between full attention and divided attention conditions in the Cued Recall tasks in the trained long-term training group ($N = 12$).



Note:

FA-FA	(Full attention at encoding; full attention at retrieval)
DA-FA	(Divided attention at encoding; full attention at retrieval)
FA-DA	(Full attention at encoding; divided attention at retrieval)
DA-DA (E)	(Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R)	(Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

Figure 25. Difference in RT performance (in milliseconds) between full attention and divided attention conditions in the Cued Recall tasks in the trained long-term training group ($N = 12$).

Summary of Asymmetrical Effect of long-term Video Game Training and Divided Attention on Encoding and Retrieval Processes

The results provide support to the differential effects of training and division of attention on encoding and retrieval processes. There was a substantial effect of divided attention at encoding (in both Free and Cued Recall tasks) on recall performance, whereas RT (or secondary task) performance was not affected greatly. On the other hand, divided attention at retrieval showed no substantial decrement in memory performance (on both Free and Cued Recall tasks) compared to the Full Attention condition, however, RT performance did show a significant decline. When attention was divided at both encoding and retrieval, recall performance was similar to the level of divided attention at encoding only. Similarly, the RT performance at encoding was in line with RT performance when attention was divided at encoding only, and RT performance at retrieval was comparable to RT performance when attention was divided at retrieval only. These findings suggest that even long-term video game training cannot alter the differential effect of divided attention on encoding and retrieval processes.

Self-assessment of Video Game Performance

The following section is an illustration of participants' self-assessment of their video game performance. The results reported here are only from the trained group who completed the assessment after completing the training. The data is analysed using percentages. The results provide the participants' view of the game they trained with as well as how they performed as well as a measure of how appropriate the training medium was for them.

Study 1

The results of the short-term training group (see Table 41) shows that most participants (84.6%) enjoyed training with the game Banjo Kazooie. It also shows that a large proportion of them found the game interesting (84.6%) and that they did not find the game boring (84.6%). The majority of participants also indicated they would like to play the game often (61.5%) and that they were totally absorbed in the game (46.2). Most participants did not find the game difficult to understand (61.6%) and revealed that they would like to play a similar game in future (53.8%).

In relation to their perception of game performance, 46.2 per cent of participants indicated that they played the game well while 69.2 per cent of participants indicated they could have played better. A large proportion of individuals however, disagreed that they played Banjo Kazooie better than other games (84.6%). They also did not agree to the statement 'Playing video games helps me improve skills on other activities' (61.6%) and most disagreed (46.2%) to recommending playing video games to their friends. Overall, these results show that a majority of participants enjoyed training with the game and that they did not have much difficulty in understanding the game.

Table 41

Percentage report of attitude to video game and self-assessment of game performance in the short-term training study ($N = 13$)

Measure	Agree or Strongly Agree	Disagree or Strongly Disagree	Not Sure
Enjoyed the game	84.6	15.4	0.0
Game was interesting	84.6	7.7	7.7
Absorbed in the game	46.2	23.1	30.8
Game was boring	0.0	84.6	15.4
Like to play game often	46.2	30.8	15.4
Played the game well	46.2	30.8	23.1
Could have played better	69.2	23.1	7.7
Game was difficult to understand	30.8	61.6	7.7
Would like to play similar game in future	53.8	23.1	23.1
Played game better than other games	7.7	84.6	7.7
Played game worse than other games	61.5	23.1	15.4
Video games improves skills	15.4	61.6	23.1
Would recommend playing video games to friends	38.5	46.2	15.4

Study 2

The results from the long-term video game training group (see Table 42) shows that 100 per cent of participants enjoyed training with the game Banjo Kazooie. Most of them also reported they found the game interesting (91.7%) and that they were totally absorbed in the game (83.3). Similarly 91.7 per cent of participants indicated they did not find the game boring and that they would like to play the game often (50.0%); however, a large proportion (41.7%) of them were also unsure of the latter. Most participants (83.3%) did not find the game difficult to understand and indicated that they would like to play a similar game in future (58.3%).

In relation to their game performance, half (50.0%) the participants indicated they played the game well and just over half (58.3%) of them indicated they could have played better. Most participants (58.4%) disagreed that they played this Banjo Kazooie better than other games. Indeed they indicated that they (41.7%) played this worse than other games (which could be because of the novelty of the game as reported by participants themselves in the post-game session). Fifty per cent of the participants agreed that video game playing could help improve their skills on other activities and about the same proportion (58.3%) indicated they would recommend playing video games to their friends. These latter results are different to that of the Study 1 where participants disagreed that video games could help improve their skills on other activities. This difference in perception could be a consequence of the long-term training group spending more time in the training sessions and hence believing that their skills could be improved and that game playing could be recommended to their friends too.

Overall, these results show that a majority of participants enjoyed training with the game and that they did not have much difficulty in understanding the game. Furthermore, it shows that most participants perceived they played the game well.

Table 42

Percentage report of attitude to video game and self-assessment of game performance in the long-term training study ($N = 12$)

Measure	Agree or Strongly Agree	Disagree or Strongly Disagree	Not Sure
Enjoyed the game	100.0	0.0	0.0
Game was interesting	91.7	8.3	0.0
Absorbed in the game	83.3	8.3	8.3
Game was boring	0.0	91.7	8.3
Like to play game often	50.0	8.3	41.7
Played the game well	50.0	16.7	33.3
Could have played better	58.3	0.0	41.7
Game was difficult to understand	0.0	83.3	16.7
Would like to play similar game in future	58.3	8.3	33.3
Played game better than other games	16.7	58.4	25.0
Played game worse than other games	41.7	41.7	16.7
Video games improves skills on other activities	50.0	8.3	41.7
Would recommend playing video games to friends	58.3	24.0	16.7

DISCUSSION

The findings of the present study provide support for the first and third hypotheses and partial support for the second hypothesis. The first hypothesis stated that training with video games enhances skills of divided attention when: (a) attention is divided at encoding, (b) attention is divided at retrieval, and (c) attention is divided at both encoding and retrieval. The second hypothesis stated that video game training affects memory processes such that: (a) when attention is divided at encoding, memory costs will be reduced along with concurrent secondary task costs, (b) when attention is divided at retrieval, memory costs will be reduced along with concurrent secondary task costs, and (c) with attention divided at both encoding and retrieval, there will be a decrease in memory costs and concurrent secondary task costs. The third hypothesis stated that video game training and divided attention affect encoding and retrieval processes differentially such that: (a) when attention is divided at encoding, memory performance will drop substantially, but the concurrent secondary task performance will not, (b) division of attention at retrieval will result in a slight drop in memory performance but will lead to a large increase in the concurrent secondary task performance, and (c) division of attention at both encoding and retrieval will result in a substantial decrease in memory performance and the concurrent secondary task performance.

Findings of the Present Study in Relation to Hypothesis 1

In relation to the first hypothesis, the study found that training with video games improves skills of divided attention. Specifically, through video game training, the ability to perform two tasks simultaneously was enhanced. The study found that training with video games improves performance on both primary and secondary tasks. This finding is the outcome of two studies that investigated the short-term and long-term training effects of video games on divided attention skills.

The findings of Study 1 show that short-term training with video games has the potential to improve skills of divided attention as demonstrated by improvement on some of the tasks wherein performance on the primary or secondary task improved after training, however, performance on both tasks did not improve substantially after training. This suggests that a one-hour training with video games was not sufficient to enhance skills of divided attention. This result was seen in all three divided attention conditions, i.e., when (a) attention was divided at encoding, (b) attention was divided at retrieval, and (c) attention was divided at both encoding and retrieval.

Performance on the primary task, i.e., word recall improved in all three divided attention conditions in the Free Recall tasks; however, there was no improvement in the secondary task (RT task) in any of the three divided attention conditions. In contrast, in the Cued Recall tasks, there was no substantial increase in word recall in all three divided attention conditions, whereas there was some improvement in the secondary task performance. Reaction Time accuracy improved when attention was divided at both encoding and retrieval. Thus these results suggest that training with video games has the potential to improve performance on a dual-attention task, but perhaps the amount of training provided was insufficient to produce more consistent results. Previous studies (e.g., Greenfield, DeWinstanley et al., 1994) found an improvement in divided visual attention skills after five hours of video game training. Therefore, in the present study, although a one-hour training was not enough to demonstrate a significant increase in divided attention skills, the findings show that even a small amount of training can improve performance on the primary or secondary task.

As expected, there was no improvement in either word recall or RT accuracy in the full attention condition,as participants were not trained to enhance full attention skills. It may be claimed that performance on a full attention task should be easier and better. This was the finding in comparison to tasks performed in all the divided attention conditions. However, without training, performance on this task was not expected to improve. There is no comparative research to show the effect of video game training on full attention skills. Performance in the full attention condition in the present study formed a baseline for comparison against performance in the divided attention conditions.

An examination of the effects of long-term training (i.e., for six hours) with video games on divided attention skills reveals that such training is beneficial to the improvement of dual-attention skills. This is demonstrated by an increase in performance seen in both the primary and secondary task after training in most of the tasks. Because performance on either task performed alone did not reach the ceiling level, it is argued that each task requires full attention when performed alone. Thus when taken together, the tasks allowed the assessment of dual-task performance. Specifically, correct word recall improved in the Free Recall tasks when (a) attention was divided at retrieval, and (b) attention was divided at both encoding and retrieval. No substantial improvement in word recall was seen when attention was divided only at encoding compared to the non-trained group. Similarly, RT accuracy improved when: (a) attention was divided at retrieval and (b) attention was divided at both encoding and retrieval. However, in the latter, RT accuracy improved only when attention was divided at encoding not when performed during division of attention at retrieval[1]. Similar to the word recall findings, there was no improvement in RT when attention was divided only at encoding.

On the Cued Recall tasks, the effects of long-term training with video games on divided attention skills produced more consistent improvement on primary and secondary tasks than on the Free Recall tasks. That is, word recall increased substantially after training in all three divided attention conditions, i.e., when (a) attention was divided at encoding, (b) attention was divided at retrieval, and (c) attention was divided at both encoding and retrieval. Likewise, RT accuracy improved significantly when (a) attention was divided at encoding and (b) attention was divided at both encoding and retrieval. In the latter, RT accuracy increased when it was measured during encoding and retrieval, compared to the Free Recall task when it improved only when assessed when attention was divided at encoding. There was no substantial improvement seen in RT accuracy when attention was divided only at retrieval. It is envisaged that the difficulty of the task could account for the lack of improvement.

The findings showing video game training as successfully enhancing divided attention skills are similar to the Greenfield, DeWinstanley et al. (1994) study in which practice with video games lead to a transfer of divided attention strategies to a new task. They showed that five hours of practice with an action arcade game improved strategies for dividing attention. The findings of the present study suggest that even using a non-action oriented video game has the potential to improve skills of divided attention. Thus players who engage with their video game sets at home are capable of transferring the skills acquired to play the game to other tasks.

---

[1] The RT task was performed twice when attention was divided at both encoding and retrieval

The skills of divided attention could aid the provision of informal education for occupations or tasks that demand skills in attending to several simultaneously occurring stimuli including instrument flying, operating heavy equipment, driving a car, military activities, and air traffic control (Greenfield, DeWinstanley et al., 1994). The transfer of such skills to other activities is supported by the findings of Broadbent (1986) and Piaget (1970) who suggested that many of the skills achieved through game playing could transfer directly to real-life activities. The studies by Baker et al. (1993) and Gopher et al. (1994) also demonstrated that skills acquired through computer game practice could transfer to flight performance.

The reasons for the ability of video games to develop divided attention skills are that video game players constantly monitor several targets appearing simultaneously at several locations on the video screen (Gagnon, 1985; Greenfield, 1984) as well as controlling different buttons on the controller and moving the joystick in appropriate directions. In addition, the video game player is required to respond to the multimodal perceptual information with coordinated motor sequences on the basis of cognitive modelling, executive planning, and evaluation of ongoing feedback (Braun & Giroux, 1989). Thus through extensive practice, video games could surreptitiously develop skills of divided attention among players. It is asserted that through long-term video game training, players usually receive large amounts of practice that enable them to attend to the tasks on screen "automatically." Thus, there is space in their conscious system to encode and attend to other tasks while simultaneously playing the games.

Indeed, the research literature on divided attention recognises the effects of practice on attentional strategies. The effect of training on improving divided attention skills may be explained through the automatic and controlled processing theory proposed by Shiffrin and Schneider's (1977) according to which performance on two or more tasks can become efficient after practice. Thus performance on the primary and secondary tasks can become automatic and devoting attention to them is no longer necessary and performance is no longer affected by the number of processes being used simultaneously but by the amount of practice received in the past (Shiffrin & Schneider, 1977). However, such automaticity results in errors. The findings of the present study show that through training with video games, performance could be enhanced on both primary and secondary tasks without being prone to many errors.

Another explanation for good performance on dual tasks could be that rather than performing both tasks at once, participants attend to them in rapid alternation (Broadbent, 1954), i.e., they may have learned to "time share" their capacity. However, once again, the findings of the present study refute this theory because there was no loss of performance on the recall or reaction time task. Rather, performance on both tasks increased. Hirst et al. (1980) and Spelke et al. (1976) also showed that division of attention could occur without alternation or automaticity. They found in their study that with sufficient practice, participants could learn to read a story and write dictated words with no loss of speed of reading or comprehension of the story. Thus the participants were able to perform multiple tasks without loss of performance. When they investigated the automaticity hypothesis, they found that the ability to divide attention is constrained primarily by the individual's level of skill, which can be developed and enhanced through sufficient practice while minimizing or eliminating errors. Therefore, they suggested that participants in their study did not perform the tasks in an automatic manner.

Large amounts of practice have also been found to lead people to becoming experts in that task compared to novices who have not received much practice

(Frensch & R.J. Sternberg, 1991). Furthermore, other studies show that extended practice can dramatically improve performance in multiple channel monitoring (Brown & Poulton, 1961; Neisser, 1976; Underwood, 1974). Taken together, these findings in conjunction with the findings of the present study highlight the role of practice in enhancing performance on dual-attention tasks. Thus they are in contrast to some studies that found a failure in the capacity to perceive stimuli accurately when attention is divided (e.g., Broadbent, 1958; Mitsuda, 1968; Reinitz et al., 1994).

Evidence from neurocognitive studies provides further support to the proposition video games improve attentional resources. For example, Koepp et al. (1998) found that striatal dopamine is released during video game play. Striatial dopamine is involved in attention (Robbins & Everitt, 1992; Schultz et al., 1993) and this could provide a possible improvement in people being able to allocate attentional resources to multiple tasks during video game play. Koepp et al. (1998) demonstrated prolonged alterations in dopamine levels after 50 minutes after the training had ended. The present study was able to demonstrate that divided attention skills could be improved through long-term training even a week after training had ended. This has implications for use of video game training to assist children with Attention Deficit Disorder (Braukus et al., 2000).

In the present study, when performance on the primary and secondary tasks was compared across the attention conditions, it was found that as expected, word recall and RT accuracy were best at full attention. In the divided attention conditions, word recall was best when attention was divided at retrieval, followed by performance when attention was divided at encoding and then when attention was divided at both encoding and retrieval. This pattern of findings was seen across Free Recall and Cued Recall tasks in both the short-term training and long-term training groups. This suggests that a concurrent task during encoding reduces memory performance, but that dividing attention during retrieval had very little effect on memory performance. These findings are similar to those of Baddeley et al. (1984), N.D. Anderson et al. (1998), Craik et al. (1996), Fernandes and Moscovitch (2000), Naveh-Benjamin et al. (1998), Naveh-Benjamin et al. (2000), and Park et al. (1989) who also found memory performance to be best in the full attention-divided attention condition, followed by recall performance with attention divided at encoding and then when attention was divided at both encoding and retrieval.

In relation to RT accuracy findings, the pattern of differences between the attention conditions was such that once again, as expected, performance was best in the full attention condition. Among the divided attention conditions, the RT accuracy performance was best when attention was divided at encoding only and in the RT performance at encoding with attention divided at both encoding and retrieval. This was followed mainly by the RT accuracy performance at retrieval when attention was divided at only retrieval and at both encoding and retrieval. Once again, this pattern of findings was seen across Free Recall and Cued Recall tasks in both the short-term training and long-term training groups. These findings suggest that divided attention at encoding has a relatively small effect on the secondary task, while division of attention at retrieval leads to a large decrease in performance on the secondary task. The findings resonate those of Baddeley et al. (1984) and Craik and his colleagues (N.D. Anderson et al., 1998; Craik et al., 1996; Fernandes & Moscovitch, 2000; Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000) who also found secondary task performance to be markedly reduced under concurrent retrieval compared to concurrent encoding.

The findings of the present study demonstrate that video game playing influences performance on a divided attention task in the same way as the process of divided attention influences performance on the primary and secondary tasks. This suggests that although video game training can enhance skills of divided attention, it cannot alter the pattern of influence related to the process of divided attention on primary and secondary tasks. However, taken together, the findings of the present study show that training with video games increases performance on primary and secondary tasks when carried out in a divided attention condition. This demonstrates that video game training could provide strategies to improve skills of divided attention, thus supporting the first hypothesis. These skills can assist in the performance of a range of tasks from improving speeded responding amongst elderly adults (Clark et al., 1987) to driving (Kramer et al., 1995) to flight performance (Gopher et al., 1994) or air traffic control (Greenfield, DeWinstanley et al., 1994).

Findings of the Present Study in Relation to Hypothesis 2

The findings of the present study provide partial support for the second hypothesis, which stated that video game training affects memory processes such that: (a) when attention is divided at encoding, memory costs will be reduced along with concurrent secondary task costs, (b) when attention is divided at retrieval, memory costs will be reduced along with concurrent secondary task costs, and (c) with attention divided at both encoding and retrieval, there will be a decrease in memory costs and concurrent secondary task costs.

The findings of the current study demonstrate that video game training affects the memory processes of encoding and retrieval by reducing costs associated with memory performance in a dual-attention condition. However, the findings do not support the proposition that video game training reduces costs associated with secondary task performance in a dual-attention condition.

The findings of Study 1 demonstrate that short-term video game training has the potential to reduce costs associated with memory performance in a dual-attention condition. This is displayed in the two of the three Free Recall tasks presented in a divided attention condition. Specifically, memory costs were reduced when: (a) attention was divided at encoding, and (b) attention was divided at retrieval. No such reduction in memory cost was seen when attention was divided at both encoding and retrieval. These findings suggest that training with video games could reduce the drop in word recall in two of the divided attention conditions compared to the full attention condition. In other words, the amount of word recall that is reduced in a dual-attention condition when compared to the full attention condition is decreased when attention is divided at either encoding or retrieval only. However, this decrease in memory cost was not seen when attention was divided at both encoding and retrieval, which is the most complex and resource intensive dual-attention condition. Perhaps the difficulty of the task led to video game training producing a nonsignificant result here.

No decrease in memory cost in any of the divided attention conditions in the Cued Recall tasks was observed. A possible explanation for this finding could be that although Cued Recall task performance may be assisted with the help of cues, they make encoding difficult because the individual has to memorise two words together with performing the concurrent RT task. Two of the three divided attention conditions required this type of memory processing. Taken together, this finding suggests that short-term video game training is not sufficient to decrease costs associated with memory in a Cued Recall task.

In relation to the effect of training on secondary task cost reduction, the findings of the present study did not reveal a substantial reduction in concurrent RT costs in all three divided attention conditions in both Free Recall and Cued Recall tasks. That is, there was no concurrent secondary task cost reduction when: (a) attention was divided at encoding, (b) attention was divided at retrieval, or (c) attention was divided at both encoding and retrieval. These findings suggest that short-term video game training does not have the capacity to influence concurrent secondary task costs.

An examination of the findings of Study 2 reveals long-term video game training could substantially reduce costs associated with memory performance in a dual-attention condition. This is displayed in most of the Free and Cued Recall tasks. Specifically, in the Free Recall tasks, training led to substantial reduction in memory cost when attention was divided at retrieval only. However, this was not seen when attention was divided at either encoding only or at both encoding and retrieval. This finding is in contrast with the pattern of reduction in memory costs seen in Study 1. Thus it may be questioned as to how a short-term training with video games leads to a reduction in costs in the latter two divided attention conditions while a long-term training with video games does not display the same finding. This can be explained by the finding related to the first hypothesis that long-term training improved memory performance substantially in most of the divided attention conditions and reduced the discrepancy in word recall between full and divided attention conditions. Therefore, memory cost may not be very great and hence there may not be a substantial reduction in costs in the long-term training group as compared to the short-term training group.

In the Cued Recall tasks, memory costs associated with all three divided attention conditions were significantly reduced through long-term video game training. Specifically, memory costs were reduced when: (a) attention was divided at encoding, (b) attention was divided at retrieval, and (c) attention was divided at both encoding and retrieval. These findings suggest that long-term training with video games could reduce the drop in word recall when attention is divided compared to the full attention condition. In other words, the amount of word recall that is reduced in a dual-attention condition compared to the full attention condition is decreased when attention is divided at either encoding, retrieval, or both.

An examination of the concurrent secondary task costs findings did not demonstrate a reduction in RT costs in Free Recall and Cued Recall tasks. This is illustrated in all three divided attention conditions, that is, when: (a) attention was divided at encoding, (b) attention was divided at retrieval, and (c) attention was divided at both encoding and retrieval. This suggests that even long-term video game training is not sufficient to reduce costs associated with concurrent secondary tasks. This finding resonates with the finding of Study 1 which showed that short-term video game training is not sufficient to reduce costs associated with the concurrent secondary task in all three divided attention conditions.

The lack of a training effect on concurrent secondary task costs could be explained by the strong influence of process of divided attention on increasing concurrent secondary task costs, which cannot be reduced significantly even through long-term video game training that can *improve* performance on a concurrent secondary task. Thus although video game training is effective to improve performance on the concurrent secondary task, it does not have the capacity to reduce costs associated with it.

Taken together, the findings related to memory and RT cost reduction provide partial support to Hypothesis 2 as they indicate that video game training affects the memory processes of encoding and retrieval by reducing costs associated with their performance in a dual-attention condition. However, the same training effect is not seen on the concurrent RT costs.

There is no comparative research to show the effect of video game training or any other method of training on memory and RT cost reduction. However, previous studies demonstrate the costs associated with performance of two simultaneous tasks. For example, Posner and Boies' (1971) study showed a slower concurrent RT when an auditory tone was presented at the same time as a letter-matching task. Similarly, Craik and colleagues (N.D. Anderson et al., 1998; Craik et al., 1996; Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000) demonstrated memory and RT costs when attention was divided at encoding or retrieval compared to the full attention condition. Park et al. (1989) also found impaired memory performance and secondary task performance when attention was divided. Likewise, air traffic controllers who carry out their jobs in a divided attention condition to a large extent have also been found to show decreased performance when the demands are too high (Barber, 1988). However, previous research has not examined whether costs associated with division of attention can be reduced through training.

An argument that could be made for the pattern of the present findings is that costs associated with divided attention are not entirely reduced but that performance on a divided attention task is improved (as seen in Hypothesis 1) through video game training. This can be explained by looking at the comparisons made to arrive at these results. When comparing whether performance is enhanced or not, the effect of training was compared between the trained and untrained groups on each of the divided attention conditions singly. On the other hand, when investigating the effects of training on memory and RT cost reduction, the performance of the trained and untrained groups were compared on each divided attention task relative to the full attention task. Hence, although an improvement is seen in performance on the divided attention conditions in the first hypothesis, the difference between performance on a full attention and divided attention task could be so high (especially on the secondary task, the RT cost) that training is not effective enough to reduce this difference.

Overall, the findings of the present study demonstrate that it is possible to reduce diminished performance associated with division of attention through video game training. Although secondary task costs were not reduced, costs associated with the primary task, i.e., encoding and retrieval performance decreased. These findings thus provide partial support to the second hypothesis. These findings are important as they demonstrate that a reduction in dual-attention task performance can be decreased through video game training, which could be important to perform a range of activities more accurately. For example, reduced costs or improved performance on a dual-attention task can assist air traffic controllers perform their job better (Greenfield, DeWinstanley et al., 1994), lead to better driving skills (Kramer et al., 1995), and improve flight performance (Gopher et al., 1994).

Findings of the present Study in Relation to Hypothesis 3

The findings of the present study provide support to the third hypothesis which stated: video game training and divided attention affect encoding and retrieval processes differentially such that: (a) when attention is divided at encoding, memory performance will drop substantially, but the concurrent secondary task performance will not, (b) division of attention at retrieval will result in a slight drop in memory but will lead to a large increase in the concurrent secondary task performance, and (c) division of attention at both encoding and retrieval will result in a substantial decrease in memory performance and the concurrent secondary task performance.

The findings of the present study demonstrate that video game training and the process of divided attention affect encoding and retrieval processes of human memory differentially such that memory performance is more affected when attention is divided at encoding or both encoding and retrieval compared to when attention is divided at retrieval. In contrast, RT or secondary task performance was more greatly affected with attention divided at retrieval compared to when attention was divided at encoding or both encoding and retrieval.

An examination of the pattern of findings of Study 1 reveals the differential effect of short-term video game training on encoding and retrieval processes of human memory. Specifically, findings from the Free Recall tasks show that in line with previous studies (e.g., Craik et al., 1996; Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000), divided attention at encoding reduces memory recall substantially from performance in the full attention condition but has no such effect on the concurrent RT performance. Conversely, divided attention at retrieval led to a smaller (compared to divided attention at encoding) reduction in recall, but a large increase in RT performance. When attention was divided at both encoding and retrieval, recall performance was found to be similar to a level found when attention was divided at encoding only. Likewise, RT performance when measured at encoding was similar to the level when attention was divided at encoding. Also, RT performance at retrieval was similar to the level when attention was divided at retrieval only. The findings with the Cued Recall tasks showed exactly the same differential effect of short-term video game training and divided attention on the encoding and retrieval processes of human memory as seen with the Free Recall tasks.

The findings suggest that short-term video game training has the same differential effect of divided attention on encoding and retrieval processes as the process of divided attention alone. Therefore, although video game training improves performance on divided attention tasks (seen in Hypothesis 1), it cannot alter the differential the influence of divided attention on encoding and retrieval processes.

In Study 2, the differential effect of long-term video game training and divided attention on encoding and retrieval processes was of the same pattern as seen in Study 1 and thus provided further support for the third hypothesis. Specifically, findings from the Free Recall tasks showed that in line with previous studies (e.g., Craik et al., 1996; Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000), with attention divided at encoding, memory performance declined significantly from the full attention condition, but RT performance did not. In contrast, division of attention at retrieval was associated with a minimal reduction in recall but with a substantial increase in RT performance. When attention was divided at both encoding and retrieval, recall performance was found to be similar to levels found when attention was divided at encoding only, i.e., word recall reduced substantially, just as in Study 1. Similarly, the concurrent RT performance at encoding corresponded to RT performance when attention was divided at encoding only and concurrent RT performance at retrieval corresponded to the level when attention was divided at retrieval only. The findings with the Cued Recall tasks reflected the same differential effect of video game training and divided attention on encoding and retrieval processes of human memory as seen with the Free Recall tasks.

The findings of Study 2 suggest that long-term training with video games has the same differential effect of divided attention on encoding and retrieval processes as the process of divided attention alone. Therefore, although video game training improves performance on divided attention tasks (seen in Hypothesis 1), it cannot alter the differential the influence of divided attention on encoding and retrieval processes.

Taken together, the findings from Study 1 and 2 support Hypothesis 2 as they indicate that video game training and the process of divided attention have a differential effect on the encoding and retrieval processes of memory by reducing memory performance to a greater extent when attention is divided at encoding or at both encoding and retrieval compared to when attention is divided at retrieval. In contrast, the differential effect on concurrent RT performance is such that RT is increased to a larger extent when attention is divided at retrieval compared to when attention is divided either at encoding only or at both encoding and retrieval.

The findings are similar to other studies in the area that have also shown the differential effect of divided attention on the encoding and retrieval processes of human memory. However, there is no comparative research to show the differential effect of video game training on the encoding and retrieval processes. Previous research has revealed that encoding and retrieval are two different memory processes and are affected by the process of divided attention differentially (N.D. Anderson et al., 1998; N.D. Anderson, 1999; Baddeley et al., 1984; Craik et al., 1996; Fernandes & Moscovitch, 2000; Naveh-Benjamin et al., 1998; Naveh-Benjamin et al., 2000; Park et al., 1989). The findings of the present study are similar to that of previous research that has found divided attention at encoding to be more disruptive to recall performance than is divided attention at retrieval. The pattern of RT performance in the present study is also similar to that found in previous studies. Craik and colleages (1996) and Park et al. (1989) demonstrated through a series of experiments that the RT or concurrent secondary task performance is affected to a larger extent by divided attention at retrieval than by divided attention at encoding.

Craik et al. (1996) explained that division of attention at encoding is associated with a reduction in memory performance because encoding processes are consciously controlled and attention demanding and therefore require greater attentional resources. On the other hand retrieval processes are automatic, obligatory or protected, and do not require attentional resources for their execution and therefore divided attention at retrieval reduces recall only minimally (Baddeley et al., 1984; Craik et al., 1996). The slowing of RT when attention is divided at retrieval is explained by the response conflict that occurs between the concurrent task (RT) and recall (Park et al. 1989). Furthermore, the differential effect of divided attention on encoding and retrieval could be explained by the theory that during encoding, memory and concurrent tasks compete for general resources, whereas during retrieval, they contend mainly for representational systems (Fernandes & Moscovitch, 2000). Thus previous research and the findings of the present study demonstrate the vulnerability of encoding processes and the resilience of retrieval processes to the influence of divided attention. The findings of the present study also demonstrate that this differential influence of the process of divided attention cannot be altered through video game training, thus showing the resiliency of the process.

Self Assessment of Video Game Playing

In relation to participants' assessment of the video game that was provided for training, it was found that most people (84.6%) in Study 1 enjoyed training with

Banjo Kazooie. In relation to their perception of game performance, just under half of the participants indicated that they played the game well while nearly three quarters of participants indicated they could have played better. The findings from Study 2 indicate that all participants enjoyed training with the game and most of them did not find the game difficult to play. In relation to their game performance, half the participants indicated they played the game well while just over half of them indicated they could have played better. Overall, the findings show that a majority of participants enjoyed training with the game and that they did not have much difficulty in understanding the game, thus proving the training mode to be a successful one. Thus participants easily learned to play the game well enough to make it interesting, but rarely were they able to play it perfectly that could have led to falling interest.

Summary of Findings of the Present Research

In summary, the findings of the present research demonstrate through Hypothesis 1 that limitations to the human information processing system could be altered through training. Specifically, the role of training on dual-task performance showed that skills of divided attention could be improved through video game training. Findings from Hypothesis 2 suggest that video game training can affect encoding and retrieval processes in a dual-attention condition. That is, video game training can reduce costs associated with memory performance when attention is divided, however, that concurrent secondary task costs could not be reduced. Findings related to the third hypothesis demonstrate that video game training affects encoding and retrieval processes in the same way as the process of divided attention. Specifically, video game training and divided attention affect encoding and retrieval processes differentially such that memory performance is affected to a larger extent when attention is divided at encoding compared to when attention is divided at retrieval, while concurrent secondary (RT) task performance is affected more reliably when attention is divided at retrieval compared to when attention is divided at encoding only.

Limitations of the Present Research

There were a few limitations associated with the present study. They include: (a) a small sample size. Overall, the study involved 50 participants, however, future studies could involve a larger sample size to demonstrate the effects of video game training on a larger representation of the population. Despite the small size, the findings of the present study show that the effects of training were strongly visible. (b) The use of only two types of recall tasks. Perhaps future studies could utilise a recognition task as well to investigate the effects of video game training on another type of memory task. However, for the purposes of the present study, the two tasks, Free Recall and Cued Recall, showed to be sufficient. (c) Provision of training with only one video game. Future studies could investigate any difference in the training effect by including more numbers of video games and also more genres of video games.

A Word of Caution

Although the current study reveals prospects for the positive development of certain cognitive skills through video game playing, the findings need to be considered in light of the game used for training and the constraint on the number of hours played in each session. The game used for training (Banjo Kazooie) was one that was nonviolent and fulfilled criteria set by the Australian Film and Literature

Classification Board regarding the genre of games liked by women. Also, the participants in the current study played the game for an hour in each session. It is not advisable that people play video games for extensive numbers of hours in one session in order to try and improve their skills of divided attention rather, to play a maximum of two hours per session depending on age and other priorities such as homework for children, work for adults, and being involved in other social/entertainment activities. Crook (1994) aptly suggests that the educational benefit of games should not be seen as 'magic bullets' that will invariably have beneficial effects upon its users. Indeed, "much depends on the relevance of the game to the skills being tested, the qualities of the game, the relationship of the game to other developmental and educational circumstances, the age and pre-existing abilities of the children (and others), and their motivations to take part" (Durkin, 1995, p. 50). This word of caution does not preclude the effects games can have on users in relation to improving skills of divided attention and reducing memory costs.

Significance of the Present Study

The present study has made some significant and original theoretical and practical contributions to knowledge.

(1) The findings of the present study have demonstrated through a rigorous and extensive study that skills of divided attention could be improved through video game training. Previous studies in the field (e.g., Greenfield, DeWinstanley et al., 1994) have not investigated this proposition thoroughly and have had methodological shortcomings. Thus the present study is a genuine attempt to bring together the effects of video game playing on cognitive skills.

(2) The study is unique as it included only women. Previous research investigating the effects of video game training have largely included only men or very few women. Thus the effects video games have on the cognitive processes of women players have not been previously investigated. This is an important contribution considering the increasing trend in the number of women interested in and playing video games.

(3) The present study has examined the influence of video game training on the memory processes of encoding and retrieval through memory cost reduction. To date, there is no previous research that has investigated the relationship between video game training and the encoding and retrieval processes of human memory. Thus the findings of the present study have demonstrated that it is possible to reduce costs associated with memory performance through video game training.

(4) The present study explored the differential effect of video game training on encoding and retrieval processes of human memory. To date, there is no previous research that has examined any alteration to the differential effect of divided attention on the encoding and retrieval processes of memory. The findings of the present study confirm the resiliency of the process of divided attention in affecting encoding and retrieval processes differentially, which cannot be altered through video game training.

Implications of the Findings of the Present Research

The findings of the present study have important implications for future research and real-world applications.

(1) The findings showing an improvement in divided attention skills through video game training could be used to train flight personnel, air traffic controllers, defence personnel, operators of heavy equipment, and motor vehicle drivers to enhance their skills of divided attention. In addition, specially designed games or simulators could be constructed for the purpose of differential testing. For example, a driving simulator to test and enhance driving skills; air combat games to assess pilot skills or for pilot training; and military games to train cadets in combat. Further, skills of divided attention are required to carry out a multitude of tasks in our every day lives; thus, playing with video games could be beneficial and improve important cognitive skills amongst its users.

(2) The findings of the present study could be applied to improving skills of divided attention amongst older people who have a decline in such skills as well as speeded processing. Clark et al. (1987) and Dustman et al. (1992) demonstrated that the decline in speeded processing could be reversed through video game training. Thus elderly participants would not only improve important cognitive skills, but could also enjoy a different leisure activity through video game training. It is envisaged that RT performance of younger participants too could be improved.

(3) The finding in relation to a decrease in memory cost through video game training has implications for use in older and younger people trying to memorise information while concurrently performing another task. Further research could be conducted in this area to investigate whether memory skills could also be improved through video game training.

(4) Future research could investigate the influence of different genres of video

games on cognitive skills.

(5) Further research in the area of improving divided attention skills needs to be conducted by including men and women.

(6) The findings of the present study have implications for use of video game training to assist children with Attention Deficit Disorder as found in another study (Braukus et al., 2000). Extensive research is required to confirm this application.

Conclusion

In conclusion, the present study has demonstrated that skills of divided attention could be enhanced through video game training. It also showed that video game training could lead to a reduction in memory costs. These cognitive skills are important to perform a range of tasks and previous research has not adequately investigated the influence of video game training on improving such skills. Thus the current study is an important attempt to demonstrate the influence of video game training on divided attention skills and reduction in memory costs and has demonstrated the use of video games as a training tool to improve cognitive capabilities. Therefore, the current study has made an original and significant contribution to knowledge. It is envisaged that real-world applications be made from the present findings.

REFERENCES

Australian Bureau of Statistics. (2002). *Communications and information technology: Use of information technology by older people.* Electronic document. Retrieved November, 2004 from www.abs.gov.au

Australian Bureau of Statistics. (2004). *Measures of a knowledge-based economy and society, Australia: Information and communications technology indicators.* Electronic document. Retrieved November, 2004 from www.abs.gov.au.

Allport, D. A., Antonis, B., & Reynolds, P. (1972). On the division of attention: A disproof of the single channel hypothesis. *Quarterly Journal of Experimental Psychology, 24*, 25-35.

Allport, A. (1986). Visual attention. In M. Posner (Ed.), *Foundations of cognitive science* (pp. 631-682.). Cambridge, MA.: MIT Press.

Anderson, J. R., & Bower, G.H. (1972). Configural properties in sentence memory. *Journal of Verbal Learning and Verbal Behavior, 11*, 594-605.

Anderson, C. M. B., & Craik, F. I. M. (1974). The effect of a concurrent task on recall from primary memory. *Journal of Verbal Learning and Verbal Behavior, 13*, 107-113.

Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review, 89*, 369-406.

Anderson, M. C., & Neely, J.H. (1996). Intereference and inhibition in memory retrieval. In E. L. Bjork & Bjork, R.A. (Eds.), *Memory* (pp. 237-313). San Diego, CA: Academic Press, Inc.

Anderson, N. D., Craik, F.I.M., Naveh-Benjamin, M. (1998). The attentional demands of encoding and retrieval in younger and older adults: 1. Evidence from divided attention costs. *Psychology and Aging, 13*(3), 405-423.

Anderson, N. D. (1999). The attentional demands of encoding and retrieval in younger and older adults: 2. Evidence from secondary task reaction time distributions. *Psychology and Aging, 14*(4), 645-655.

Anderson, J. R. (2000). *Cognitive Psychology and its Implications*. New York: Worth Publishers.

Anderson, C. A., & Dill, K. E. (2000). Video Games and Aggressive Thoughts, Feelings, and Behavior in the Laboratory and in Life. *Journal of Personality and Social Psychology, 78*(4), 772-790.

Atkinson, R. C., & Shiffrin, R.M. (1968). Human memory: a proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation* (Vol. 2, pp. 89-195). New York: Academic Press.

Atkinson, R. C., & Shiffrin, R.M. (1971). The control of short-term memory. *Scientific American, 225*, 82-90.

Avolio, B. J., Kroeck, K. G., & Panek, P. E. (1985). Individual differences in information-processing ability as a predictor of motor vehicle accidents. *Human Factors, 27*(5), 577-587.

Baddeley, A. D., & Hitch, G. (1974). Working memory. In G. A. Bower (Ed.), *The psychology of learning and motivation* (pp. 47-89). New York: Academic Press.

Baddeley, A., Lewis, V., Eldridge, M., & Thomson, N. (1984). Attention and retrieval from long-term memory. *Journal of Experimental Psychology: General., 113*(4), 518-540.

Baddeley, A. (1986). *Working memory.* Cambridge, England:Clarendon Press/Oxford University Press.

Baddeley, A. D. (1999). *Essentials of Human Memory.* East Sussex: Psychology Press Ltd.

Baker, D., Prince, C., Shrestha, L., Oser, R., & Salas, E. (1993). Aviation computer games for crew resource management trianing. *The International Journal of Aviation Psychology, 3*(2), 143-156.

Barber, P. (1988). *Applied cognitive psychology: An information-processing framework.* London: Methuen.

Battig, W. F., & Montague, W.E. (1969). Category norms for verbal items in 56 categories: A replication and extension of the Connecticut Category Norms. *Journal of Experimental Psychology Monograph, 80*(3), 1-46.

Bjork, R. A. (1975). Retrieval as a memory modifier. In R. Solso (Ed.), *Information processing and cognition: the Loyola Symposium.* (pp. 123-144). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bjork, R. A. (1975). Short- term storage: the ordered output of a central processor. In F. Restle, R.M. Shiffrin, N.H. Castellan, H.R. Lindeman & D. B. Pisoni (Eds.), *Cognitive Theory* (Vol. 1). Hillsdale NJ: Erlbaum.

Bouma, H. B., D.G. (1984). *Attention and Performance X: Control of language processes.* Paper presented at the Tenth International Symposium on Attention and Performance, Netherlands.

Bransford, J. D., Franks, J. J., Morris, C. D., & Stein, B. S. (1979). Some general constraints on learning and memory research. In L. S. Cermak & F. I. M. Craik (Eds.), *Levels of precessing in human memory* (pp. 331- 354). Hillsdale, NJ: Lawrence Erlbaum Associates.

Braukus, M., Henry, K., & Gardner, J. (2000). *Video games may lead to better health through new NASA technology* (No. 00-063, Electronic resource). Hampton, Virginia, USA: National Aeronautics and Space Administration.

Braun, C. M. J., & Giroux., J. (1989). Arcade video games: Proxemic, cognitive and content analyses. *Journal of Leisure Research, 21*, 92-105.

Broadbent, D. E. (1954). The role of auditory localisation in attention and memory span. *Journal of Experimental Psychology, 47*, 191-196.

Broadbent, D. (1958). *Perception and Communication*. New York: Pergamon.

Broadbent, D. E. (1971). *Decision and Stress*. London: Academic Press.

Broadbent, D. E. (1986). The enterprise of performance. *Quarterly Journal of Experimental Psychology, 38A*, 151-162.

Brooks, B. D. (1983). Untitled. In S. S. Baughman & P. D. Clagett (Eds.), *Papers and Proceedings of the Symposium Video game and human development: a research agenda for the 80's*. Cambridge, Massachusetts: Gutman Library, Harvard Graduate School of Education.

Brown, I. D., & Poulton, E.C. (1961). Measuring the spare "mental capacity" of care drivers by a subsidiary task. *Ergonomics, 4*, 35-40.

Buckalew, L. W., & Buckalew, P.B. (1983). Behavioral management of exceptional children using video games as reward. *Perceptual and Motor Skills, 56*, 580.

Bundesen, C. (1990). Theory of visual attention. *Psychological Review, 97*, 523-527.

Butterfield, F. (1983, May, 24.). Video game specialists come to Harvard to praise Pac-man, not bury him. *New York TImes,* p. 22.

Cassell, J., & Jenkins, H. (1998). *From Barbie to Mortal Kombat: Gender and computer games*: The MIT Press.

Cedrus Corporation. (1999). *Superlab* (Version 2). San Pedro, CA: Cedrus Corporation.

Cherry, E. C. (1953). Some experiments on the recognition of speech with one and two ears. *Journal of the Acoustical Society of America, 25*, 975-979.

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*, 82-85.

Cohen, A. R., Fink, S. L., Gadon, H., & Willits, R. D. (1980). *Effective behaviour in organisations: learning from the interplay of cases, concepts and student experiences*. USA: Richard D Irwin, Inc.

Colwell, J., Grady, C., & Rhaiti, S. (1995). Computer games, self-esteem and gratification of needs in adolescents. *Journal of Community & Applied Social Psychology, 5*(3), 195-206.

Colwell, J., & Payne, J. (2000). Negative correlates of computer game play in adolescents. *British Journal of Psychology, 91*(3), 295-310.

Compaine, B. M. (1983). The new literacy. *Daedelus, 112*(129-142).

Cooper, J., & Mackie, D. (1986). Video games and aggression in children. *Journal of Applied Social Psychology, 16*, 726-744.

Cowan, N. (1997). *Attention and Memory: An Integrated Framework.* New York: Oxford University Press, Inc.

Cowley, J. (1987). Silk. In M. McLeod & L. Wevers (Eds.), *Women's work: contemporary short stories by New Zealand women.* (pp. 204 -209). Auckland, N.Z: Oxford University Press.

Craik, F. I. M., Lockhart, R.S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11*, 671-684.

Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General, 104*(3), 268-294.

Craik, F. I. M. (1983). On the transfer of information from temporaray to permanent memory. *Philosophical Transactions of the Royal Society of London, Series B302*, 341- 359.

Craik, F. I., & McDowd, J. M. (1987). Age differences in recall and recognition. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 13*(3), 474-479.

Craik, F. I. M., Govoni, R., Naveh-Benjamin, M., & Anderson, N.D. (1996). The effects of divided attention on encoding and retrieval processes in human memory. *Journal of Experimental Psychology: General., 125*(2), 159-180.

Craik, F. I. M. (2000). Age-related changes in human memory. In D. C. Park & Schwarz, N. (Eds.), *Cognitive Aging: A Primer* (pp. 75-92). Philadelphia, P.A.: Taylor & Francis.

Crosby, J. V., & Parkinson, S.R. (1979). A dual task investigation of pilots' skill level. *Ergonomics, 22*(12), 1301-1313.

Crowder, R. G. (1976). The locus of the lexicality effect in short-term memory for phonologically identical lists. *Bulletin of the Psychonomic Society, 7*(4), 361-363.

Cupitt, A., & Stockbridge, S. (1996). *Families and Electronic Entertainment.* Sydney: Australian Broadcasting Authority and Office of Film and Literature Classification.

De Lisi, A. V. (2003). Rod Cocking's legacy: the development of psychological distancing. *Journal of Applied Developmental Psychology, 24*(6), 697-711.

Deutsch, J. A., & Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological Review, 70*(1), 80-90.

Donchin, E. (1983). *Videogames and learning.* Paper presented at the Videogames and Human Development: A Research Agenda for the '80's, Harvard University, Cambridge, MA.

Donchin, E. (1995). Video games as research tools: The Space Fortress game. *Behavior Research Methods, Instruments, & computers, 27*(2), 217-223.

Durkin, K. (1995). *Computer Games: Their effects on young people: A Review.* Sydney: Office of Film and Literature Classification.

Durkin, K., & Aisbett, K. (1999). *Computer Games and Australians Today.* Sydney, NSW: Office of Film and Literature Classification.

Durkin, K., & Barber, B. (2002). Not so doomed: Computer game play and positive adolescent development. *Journal of Applied Developmental Psychology, 23*(4), 373-392.

Dustman, R. E., Emmerson, R.Y., Steinhaus, L.A., Shearer, D.E., & Dustman, T.J. (1992). The effects of videogame playing on neuropsychological performance of elderly individuals. *Journal of Gerontology: Psychological Sciences, 47*(3), 168-171.

Duzel, E., Cabeza, R., Picton, T.W., Yonelinas, A.P., Scheich, H., Heinze, H-J., & Tulving, E. (1999). Task-related and item-related brain processes of memory retrieval. *Proceedings of the National Academy of Sciences, USA, 96*(4), 1794-1799.

Ebbinghaus, H. (1885). *Memory: a contribution to experimental psychology* (H. A. Ruger & C. E. Bussenius, Trans.). New York: Dover Publications.

Egli, E. A., & Meyers, L. S. (1984). The role of video game playing in adolescent life: Is there reason to be concerned? *Bulletin of the Psychonomic Society, 22*(4), 309-312.

Entertainment Software Rating Board. (2002). *American ratings for video/computer games*. Retrieved 6 June, 2002, from www.esrb.org

Farrelly, S. (2001). Banjo-Tooie. *Nintendo Gamer, 36,* 30-37.

Fernandes, M. A., & Moscovitch, M. (2000). Divided attention and memory: Evidence of substantial interference effects at retrieval and encoding. *Journal of Experimental Psychology: General, 129*(2), 155-176.

Frensch, P. A., & Sternberg., R.J. (1991). Expertise and intelligent thinking: When is it worse to know better? In R. J. Sternberg & P. A. Frensch (Eds.), *Complex Problem Solving: Principles and Mechanisms*. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Funk, J. B. (1993). Reevaluating the impact of video games. *Clinical Pediatrics*, 86-90.

Gabel, D. (1983). What's in a game? *Personal Computing, April,* 63-69.

Gabrieli, J. D. E. (1998). Cognitive neuroscience of human memory. *Annual Review of Psychology, 49*, 87-105.

Gagnon, D. (1985). Videogames and spatial skills: An exploratory study. *Educational Communication and Technology Journal, 33*, 263-275.

Gardner, J. E. (1993). Nintendo Games. In C. E. Schaefer, & Cangelosi, D.M. (Eds.), *Play Therapy Techniques* (pp. 273-286). New Jersey: Jason Aronson Inc.

Gfk Australia (personal communication, December, 2004). *Sales figures of video and computer games in Australia.* Sydney: Gfk Australia.

Gibb, G. D., Bailey, J.R., Lornbirth, T.T., & Wilson, W.P. (1983). Personality differences between high and low electronic video game users. *Journal of Psychology, 114*, 143-152.

Gibson, E., & Rader, N. (1979). Attention: Perceiver as performer. In G. Hale & M. Lewis (Eds.), *Attention and Cognitive Development* (pp. 1-22). New York: Plenum.

Goldstein, A. P. (1994). *The ecology of agression: Places, people, prevention.* New York: Plenum.

Goolkasian, P. (1995). Psychology and Information Technology. *Behavior Research Methods, Instruments and Computers, 27*(2), 109-115.

Gopher, D. (1982). A selective attention test as a predictor of success in flight training. *Human Factors, 24*(2), 173-183.

Gopher, D. (1990). Dual-task performance. In M. W. Eysenck (Ed.), *The Blackwell Dictionary of Cognitive Psychology* (pp. 111-116). Oxford, UK: Basil Blackwell.

Gopher, D., Weil, M., & Bareket, T. (1994). Transfer of skill from a computer game trainer to flight. *Human Factors, 36*(3), 387-405.

Gorriz, C. M., & Medina, C. (2000). Engaging girls with computers through software games, *Communications of the ACM* (Vol. 43, pp. 42-49): Association for Computing Machinery.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*(6939), 534-537.

Greene, R. L. (1986). A common basis for recency effects in immediate and delayed recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*(3), 413-418.

Greenfield, P. M. (1983). *Video games and cognitive skills.* Paper presented at the Video games and human development: Research agenda for the '80's, Cambridge, MA.

Greenfield, P. M. (1984). *Mind and media: The effects of television, video games, and computers.* Cambridge: Harvard University Press.

Greenfield, P. M. (1989). I videogiochi come strumenti della socializzazione cognitiva (Video games as tools of cognitive socialization). *Psicologia Italiana, 10*, 38-48.

Greenfield, P. M. (1993). Representational competence in shared symbol systems: Electronic media from radio to video games. In R. R. Cocking & K.A. Renninger (Eds.), *The development and meaning of psychological distance* (pp. 161-183). Hillsdale: Erlbaum.

Greenfield, P. M. (1994). Video Games as Cultural Artifacts. *Journal of Applied Developmental Psychology, 15*, 3-12.

Greenfield, P. M., Camaioni, L., Ercolani, P., Lauber, B.A., & Perucchini, P. (1994). Cognitive socialization by computer games in two cultures: Inductive discovery or mastery of an iconic code? *Journal of Applied Developmental Psychology, 15*, 59-85.

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*, 105-123.

Greenfield, P. M., Brannon, C., & Lohr, D. (1994). Two-Dimensional representation of movement through three-dimensional space: the role of video game expertise. *Journal of Applied Developmental Psychology, 15*, 87-103.

Greenfield, P. M., & Cocking, R. R. (1996). *Interacting with video.*: Ablex Publishing.

Griffiths, M. D. (1991). Amusement machine playing in childhood and adolescence: A comparative analysis of video games and fruit machines. *Journal of Adolescence, 14*, 53-73.

Griffiths, M. (1993). Are computer games bad for children? *The Psychologist: Bulletin of the British Psychological Society, 6*, 401-407.

Griffiths, M. D., & Hunt, N. (1995). Computer game playing in adolescence: Prevalence and demographic indicators. *Journal of Community & Applied Social Psychology, 5*(3), 189-193.

Griffiths, M. (1997). Computer game playing in early adolescence. *Youth & Society, 29*(2), 223-238.

Griffiths, M. (2004). Editorial: Can Videogames Be Good for Your Health? *Journal of Health Psychology, 9*(3), 339-344.

Gutman, D. (1983). Finding an heir for Pac-Man. *Psychology Today, 17*, 10.

Hartley, A. A., & Little, D.M. (1999). Age-related differences and similarities in dual-task interference. *Journal of Experimental Psychology: General, 128*(4), 416-449.

Hedden, C. (1997). An automated data collector for the study of human-computer interaction. *Computers in Human Behavior, 13*(2), 205-227.

Heilman, R. M., Watson, R.T., Valenstein, E., & Damasio, A.R. (1983). Location of lesions in neglect. In A. Kertez (Ed.), *Localization in Neuropsychology* (pp. 319-331). New York: Academic Press.

Helmuth, L. (2000). Video game images persist despite amnesia. *Science, 290*(5490), 247-249.

Hirst, W., Spelke, E.S., Reaves, C.C., Caharack, G., & Neisser, U. (1980). Dividing attention without alternation or automaticity. *Journal of Experimental Psychology: General, 109*(1), 98-117.

Hirst, W. (1986). The psychology of attention. In J. E. LeDoux, & W. Hirst (Eds.), *Mind and brain* (pp. 105-141). Cambridge, England: Cambridge University Press.

James, W. (1890). *The Principles of Psychology*. New York: Holt.

Johnson, R. G. (1993). High tech play therapy. In C. E. Schaefer, & D.M. Cangelosi (Eds.), *Play therapy techniques* (pp. 281-286). New Jersey: Jason Aronson Inc.

Johnston, W. A., Greenberg, S. N., Fisher, R. P., & Martin, D. W. (1970). Divided attention: A vehicle for monitoring memory processes. *Journal of Experimental Psychology, 83*(1), 164-171.

Johnston, W. A., Griffith, D., & Wagstaff, R. R. (1972). Speed, accuracy, and ease of recall. *Journal of Verbal Learning & Verbal Behavior, Vol. 11*(4), 512-520.

Kafai, Y. B. (1996). Gender differences in children's constructions of video games. In P. M. Greenfield & R. R. Cocking (Eds.), *Interacting with video.* (pp. 39-66): Ablex Publishing.

Kafai, Y. B. (1998). Video game designs by girls and boys: Variability and consistency of gender differences. In J. Cassell & H. Jenkins (Eds.), *From Barbie to Mortal Kombat: Gender and computer games.* (pp. 90-114): The MIT Press.

Kahana, M. J. (2000). Contingency analyses of memory. In E. Tulving & F. I. M. Craik (Eds.), *Oxford handbook of memory.* (pp. 59-72): Oxford University Press.

Kahneman, D. (1973). *Attention and effort.* Eaglewood Cliffs: Prentice - Hall.

Kahneman, D. T., A. (1984). Changing views of attention and automaticity. In R. Parasuraman & D. R. Davies (Eds.), *Varieties of Attention.* Orlando, Florida: Academic Press.

Kaplan, S., & Kaplan, S. (1981). Video games, sex, and sex differences. *Social Science, 56*, 208-212.

Kapur, S., Craik, F.I.M., Tulving, E., Wilson, A.A., Houle, S., & Brown, G.M. (1994). *Neuroanatomical correlates of encoding in episodic memory: Levels of processing efffect.*, United States of America.

Kapur, S., Craik, F.I.M., Jones, C., Brown, G.M., Houle, S., & Tulving, E. (1995). Functional role of the prefrontal cortex in retrieval of memories: A PET study. *NeuroReport, 6*, 1880-1884.

Kennedy, R. S., Bittner Jr., A.C., & Jones, M.B. (1981). Video-game and conventional tracking. *Perceptual and Motor Skills, 53*, 310.

Kestenbaum, G. I., & Weinstein, L. (1985). Personality, psychopathology, and developmental issues in male adolescent game use. *Journal of the American Academy of Child Psychiatry, 24*(3), 330.

Kiesler, S., Sproull, L., & Eccles, J.S. (1983). Second class citizens. *Psychology Today, 17*(3), 42-47??

Klatzky, R. L. (1984). *Memory and awareness.* New York: Freeman & Company.

Knowles, W. B. (1963). Operator loading tasks. *Human Factors, 4*, 155-161.

Koepp, M. J., Gunn, R.N., Lawrence, A.D., Cunningham, V.J., Dagher, A., Jones, T., Brooks, D.J., Bench, C.J., & Grasby, P.M. (21 May, 1998). Evidence for striatal dopamine release during a video game. *Nature, 393*, 266-268.

Kolers, P. A. (1973). Remembering operations. *Memory & Cognition, 1*(3), 347-355.

Kramer, A. F., Larish, J. F., & Strayer, D. L. (1995). Training for attentional control in dual task settings: A comparison of young and old adults. *Journal of Experimental Psychology: Applied, 1*(1), 50-76.

Kucera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English.* Providence: Brown University Press.

Laberge, D. (1975). Acquistion of automatic processing in perceptual and associative learning. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance V.* New York: Academic Press.

Lepper, M. R. (1985). Microcomputers in education. *American Psychologist, 40*(1), 1-18.

Lin, S., & Lepper, M.R. (1987). Correlates of children's usage of videogames and computers. *journal of Applied Social Psychology, 17*(1), 72-93.

Lindman, H.R. (1974). *Analysis of variance in complex experimental designs.* San Francisco: W.H. Freeman.

Lintern, G., & Kennedy, R.S. (1984). Video game as a covariate for carrier landing research. *Perceptual and Motor Skills, 58*, 167-172.

Lockhart, R. S., Craik, F. I. M., & Jacoby, L. L. (1976). Depth of processing, recognition and recall: some aspects of a general memory system. In J. Brown (Ed.), *Recall and recognition*. London: Wiley.

Lockhart, R. S. (2000). Methods of memory research. In E. Tulving & F. I. M. Craik (Eds.), *Oxford handbook of memory*. (pp. 45-57): Oxford University Press.

Loftus, G. R., & Loftus, E.F. (1983). *Mind at Play*. New York: Basic Books, Inc.,.

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review, 95*(4), 492-527.

Logan, G. D. (1992). Attention and preattention in theories of automaticity. *American Journal of Psychology, 105*(2), 317-339.

Logan, G. D. (1996). The CODE theory of visual attention: An integration of space-based and object-based attention. *Psychological Review, 103*, 603-649.

Lowenstein, D. (2000, 6/6/00). Who says 43% of PC gamers are women? *WomenGamers.com,* 1-2.

Maisel, A. (1997). *Software for girls: a market is discovered.* Retrieved September, 2000, from http://www.superkids.com/aweb/pages/features/girls/market1.shtml

Malone, T. W. (1981). Toward a theory of intrinsically motivating instruction. *Cognitive Science, 4*, 333-369.

Malone, T.W. (1981). What makes computer games fun? *BYTE*, 258-277.

Mandinach, E. B., & Corno, L. (1985). Cognitive engagement variations among students of different ability level and sex in a computer problem solving game. *Sex Roles, 13*, 241-251.

Mantyla, T. (1986). Optimizing cue effectiveness: recalls of 500 and 600 incidentally learned words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*, 66-71.

Markel, H., & Oski, F.A. (1996). Video games and VCRs. In H. Markel, & F.A. Oski (Eds.), *The Practial Pediatrician: The A to Z guide to your child's health, behavior, and safety* (pp. 303-305). New York: W.H.Freeman and company.

Marshall, J. (2002). *Learning with technology: evidence that educational technology can, and does, support learning.* Alexandria, VA: Cable in the Classroom.

Martin, D. W. (1970). Residual processing capacity during verbal organization in memory. *Journal of Verbal Learning & Verbal Behavior, 9*(4), 391-397.

Massaro, D. W., & Cowan, N. (1993). Information processing models: microscopes of the mind. *Annual Review of Psychology, 44*, 383-408.

Matlin, M. W. (1998). *Cognition* (4th ed.). Orlando.: Harcourt Brace & Company.

McDermott, K. B., Buckner, R.L., Petersen, S.E., Kelley, W.M., & Sanders, A.L. (1999). Set- and code-specific activation in the frontal cortex: An fMRI study of encoding and retrieval of faces and words. *Journal of Cognitive Neuroscience, 11*(6), 631-640.

McLeod, P. D. (1977). A dual task response modality effect: Support for multi-processor models of attention. *Quarterly Journal of Experimental Psychology, 29*, 651-667.

McLeod, P. D. (1978). Does probe RT measure central processing demand? *Quarterly*

Journal of Experimental Psychology, 30, 83-89.

McLuhan, M. (1964). *Understanding media: the extensions of man.* London: Routlegde and Kegan Paul.

McLuhan, M. (2001). *Understanding media: the extensions of man.* London: Routledge.

McSwegin, P. J., Pemberton, C., & O'Banion, N. (1988). The effects of controlled videogame playing on the eye-hand coordination and reaction time of children. In J. E. Clark & J. H. Humphrey (Eds.), *Advances in motor development research, Vol. 2.* (pp. 97-102). New York: AMS Press, Inc.

Mesulam, M. M. (1987). Attention, confusional states and neglect. In M. M. Mesulam (Ed.), *Principles of Behavioral Neurology* (pp. 125-168). Philadelphia: F.A. Davis.

Microsoft. (1996). *Microsoft knows games.* Redmond, WA: Microsoft Corporation.

Mirsky, A. F. (1996). Disorders of attention: A neuropsychological perspective. In G. R. Lyon & N.A. Krasnegor (Eds.), *Attention, Memory, and Executive Function* (pp. 71-95). Baltimore, Maryland: Paul H. Brookes Publishing Co.

Mitchell, E. (1985). The dynamics of family interaction around home video games. *Marriage and Family Review, 8*(1 & 2), 121-135.

Mitsuda, M. (1968). Effects of a subsidiary task on backward recall. *Journal of Verbal Learning and Verbal Behavior, 7*, 722-725.

Moray, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology, 9*, 59-90.

Moray, N. (1993). Designing for attention. In A. Baddeley & L. Weiskrantz (Eds.), *Attention: Selection, Awareness, and Control - A Tribute to Donald Broadbent* (pp. 111-134). New York: Oxford University Press Inc.

Morlock, H., Yando, T., & Nigolean, K. (1985). Motivation of video game players. *Psychological Reports, 57*(1), 247-250.

Morris, C. D., Bransford, J.D., & Franks, J.J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior, 16*, 519-533.

Morris, C. D., Stein, B. S., & Bransford, J. D. (1979). Prerequisites for the utilization of knowledge in the recall of prose passages. *Journal of Experimental Psychology: Human Learning & Memory, 5*(3), 253-261.

Moscovitch, M. (1994). Cognitive resources and dual-task interference effects at retrieval in normal people: The role of the frontal lobes and medial temporal cortex. *Neuropsychology, 8*(4), 524-534.

Naveh-Benjamin, M., Craik, F.I.M., Guez, J., & Dori, H. (1998). Effects of divided attention on encoding and retrieval processes in human memory: Further support for an asymmetry. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*(5), 1091-1104.

Naveh-Benjamin, M., Craik, F.I.M., Gavrilescu, D., & Anderson, N.D. (2000). Asymmetry between encoding and retrieval processes: Evidence from divided attention and a calibration analysis. *Memory & Cognition, 28*(6), 965-976.

Nawrocki, L. H., & Winner, J.L. (1983). Video games: Instructional potential and classification. *Journal of Computer-Based Instruction, 10*(3 &4), 80-82.

Neisser, U., & Becklen, R. (1975). Selective looking: Attending to visually significant events. *Cognitive Psychology, 7*, 480-494.

Neisser, U. (1976). *Cognition and Reality*. New York: W.H. Freeman.

Nelson, D. L., Reed, V.S., & McEvoy, C.L. (1977). Encoding strategy and sensory and semantic interference. *Memory & Cognition, 5*(4), 462-467.

Nelson, D. L. (1979). Remembering pictures and words: Appearance, significance, and name. In L. S. Cermak & F. I. M. Craik (Eds.), *Levels of Processing in Human Memory* (pp. 45-76). Hillsdale, NJ: Erlbaum.

Nelson, T. M., & Carlson, D.R. (1985). Determining factors in choice or arcade games and their consequences upon young male players. *Journal of Applied Social Psychology, 15*, 124-139.

Newell, A., & Rosenbloom, P.S. (1981). Mechanisms of skill acquisition and the law of practice. In J. R. Anderson (Ed.), *Cognitive Skills and their acquisition* (pp. 1-55). Hillsdale, NJ: Erlbaum.

Norman, D. A., & Bobrow, D.G. (1975). On data-limited and resource-limited processes. *Cognitive Psychology, 7*, 44-64.

North, R. A., & Gopher, D. (1976). Measures of attention as predictors of flight performance. *Human Factors, 18*(1), 1-14.

O'Craven, K. M., Downing, P.E., & Kanwisher, N. (7 October, 1999). fMRI evidence for objects as the units of attentional selection. *Nature, 401*, 584-587.

Office of Film and Literature Classification. (2003). *Guidelines for the classification of films and computer games* (Electronic resource). NSW: Office of Film and Literature Classification.

Okagaki, L., & Frensch, P.A. (1994). Effects of video game playing on measures of spatial performance: Gender effects in late adolescence. *Journal of Applied*

Developmental Psychology, 15, 33-58.

Orosy-Fildes, C., & Allan, R. W. (1989). Psychology of computer use: XII. Videogame play: Human reaction time to visual stimuli. *Perceptual & Motor Skills, 69*(1), 243-247.

Park, D. C., Smith, A.D., Dudley, W.N., & Lafronza, V.N. (1989). Effects of age and divided attention task presented during encoding and retrieval on memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition., 15*(6), 1185-1191.

Pashler, H., & Carrier, M. (1996). Structures, processes and the flow of information. In E. L. Bjork & Bjork, R.A (Eds.), *Memory* (2nd ed., pp. 3-29). San Diego, California: Academic Press, Inc.

Pesce, M. (2000). *The playful world: How technology transforms our imagination.* New York: Ballantine Books.

Piaget, J. (1970). *Genetic Epistemology* (E. Duckworth, Trans.). New York: Columbia University Press.

Porter, D. B. (1991). Computer games and cognitive processes: Two tasks, two modes, too much? *British Journal of Psychology, 82*, 343-357.

Porter, D. B. (1995). Computer games: Paradigms of opportunity. *Behavior Research Methods, Instruments, & Computers, 27*(2), 229-234.

Posner, M. I., & Boies, S.J. (1971). Components of attention. *Psychological Review, 78*, 391-408.

Posner, M. I. S., C.R.R. (1975). Attention and cognitive control. In R. L. Solso (Ed.), *Information Processing and Cognition: The Loyola Symposium* (pp. 55-85).

Hillsdale, NJ: Erlbaum.

Posner, M. I., Snyder, C.R.R., & Davidson, B.J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology: General, 109*(2), 160-174.

Posner, M. I., & Petersen., S.E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13*, 25-42.

Posner, M. I., & Rothbart, M.K. (1991). Attentional mechanisms and conscious experience. In A. D. Milner & M. D. Rugg (Eds.), *The Neuropsychology of Consciousness* (pp. 91-111). London: Academic Press.

Posner, M. I. (1993). Attention before and during the decade of the brain. In D. E. Myer & S. M. Kornblum (Eds.), *Attention and performance XIV: Synergies in experimental psychology, artifical intelligence and cognitive neuroscience*. Cambridge, MA: MIT Press.

Provenzo, Jr, E. F. (1991). *Video kids: Making sense of Nintendo*: Harvard University Press.

Radencich, M. C. (1984). From Dick and Jane to Tron. *Reading World, 24*, 1-3.

Reinitz, M. T., Morrissey, J., & Demb, J. (1994). Role of attention in face encoding. *Journal of Experimental Psychology: Learning, Memory, and Cognition., 20*, 161-168.

Rheingold, H. (1983). Video games go to school. *Psychology Today, 17*(9), 361-363.

Robbins, T. W., & Everitt, B. J. (1992). Functions of dopamine in the dorsal and ventral striatum. In T. W. Robbins (Ed.), *Seminars in the Neurosciences* (Vol. 4, pp. 119-127). London: Saunders.

Roberts, D. F., Foehr, U. G., Rideout, V. J., & Brodie, M. (1999). Kids and media at the new millennium. In. Menlo Park, CA: The Henry J. Kaiser Family Foundation.

Robertson, I. H., Ward, T., & Ridgeway, V. (1994). *The test of everyday attention*. Bury St. Edmunds: The Thames Valley Test Company.

Roediger, III, H. L., & Guynn, M. J. (1996). Retrieval processes. In E. L. Bjork & R. A. Bjork (Eds.), *Memory*. (pp. 197-236). San Diego, CA: Academic Press, Inc.

Rolfe, J. M. (1971). The secondary task as a measure of mental load. In W.T. Singleton, J. G. Fox & D.Whitfield (Eds.), *Measurement of Man at Work*. London: Taylor and Francis.

Rundus, D., & Atkinson, R. C. (1970). Rehearsal processes in free recall: A procedure for direct observation. *Journal of Verbal Learning & Verbal Behavior, 9*(1), 99-105.

Rundus, D. J. (1971). *An analysis of rehearsal processes in free recall.* Dissertation Abstracts International, 32(2), 1257.

Ryan, E. B. (1994). Memory for goblins: a computer game for assessing and training working memory skill. *Computers in Human services, 11*(1-2), 213-218.

Schacter, D. L., & Tulving, E. (1994). *Memory systems*. Cambridge, MA: The MIT Press.

Schneider, W. S., R.M. (1977). Controlled and automatic processing: I. Detection, search, and attention. *Psychological Review, 84*, 1-66.

Schneider, W. (1985). Toward a model of attention and the development of automatic processing. In M. I. Posner & O. S. Marin (Eds.), *Attention and Performance XI* (pp. 474-492). Hillsdale, NJ: Erlbaum.

Schribner, S., & Cole, M. (1981). *The psychology of literacy*. Cambridge: Harvard University Press.

Schulman, A. I. (1974). Memory for words recently classified. *Memory & Cognition,* *2*(1), 47-52.

Selnow, G. W. (1984). Playing videogames: The electronic friend. *Journal of Communication, 34*, 148-156.

Selst, M. V. (1997). Decision and Response in dual-task interference. *Cognitive Psychology, 33*, 266-307.

Shallice, T., Fletcher, P., Frith, C.D., Grasby, P., Frackowiak, R.S.J., & Dolan, R.J. (14 April, 1994). Brain regions associated with acquisition and retrieval of verbal episodic memory. *Nature, 368*, 633-635.

Shallice, T., & Warrington, E. K. (1970). Independent functioning of verbal memory stores: A neuropsychological study. *Quarterly Journal of Experimental Psychology, 22*(2), 261-273.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84*, 127-190.

Sigel, I. E., & Cocking, R.R. (1977). Cognition and communication: A dialectic paradigm for development. In M. Lewis & Rosenblum, L.A. (Eds.), *Interaction, conversation, and the development of language: The origins of behavior* (Vol. 5, pp. 207-226). New York: Academic.

Skinner, B. F. (1953). *Science and human behavior*. New York: Macmillan.

Smith, C. L., & Stander, J.M. (1981). Human interaction with computer simulation. *Simulation & Games, 12*(3), 345-360.

Spelke, E. S., Hirst, W.C., & Neisser, U. (1976). Skills of divided attention. *Cognition, 4*, 215-230.

Standing, L., Conezio, J., & Haber, R. N. (1970). Perception and memory for pictures: Single-trial learning of 2500 visual stimuli. *Psychonomic Science, 19*(2), 73-74.

Sternberg, R. J. (1996). *Cognitive psychology.*: Harcourt Brace College Publishers.

Stoffregen, T. A., & Becklen, R.C. (1989). Dual attention to dynamically structured naturalistic events. *Perceptual and Motor Skills, 69*, 1187-1201.

Stuart-Hamilton, I. (1995). *Dictionary of cognitive psychology.* Jessica Kingsley Publishers, Ltd.

Styles, E. (1997). *The Psychology of Attention.* East Sussex, UK: Psychology Press Ltd.

Subrahmanyam, K., & Greenfield, P.M. (1994). Effect of video game practice on spatial skills in girls and boys. *Journal of Applied Developmental Psychology, 15*, 13-32.

Subrahmanyam, K., Kraut, R. E., Greenfield, P., & Gross, E. (2001). New forms of electronic media: the impact of interactive games and the internet on cognition, socialization, and behavior. In D. Singer & J. Singer (Eds.), *Handbook of Children and the Media* (pp. 73-99). Los Angeles, CA: Sage.

The Macquarie Dictionary. (2001). New South Wales: The Macquarie Library Pty Ltd.

Thomson, D. M., & Tulving, E. (1970). Associative encoding and retrieval: Weak and strong cues. *Journal of Experimental Psychology, 86*(2), 255-262.

Treisman, A. (1964). Verbal cues, language, and meaning in selective attention. *American Journal of Psychology, 77*, 206-219.

Treisman, A. G., G. (1980). A feature-integration theory of attention. *Cognitive Psychology, 12*, 97-136.

Treisman, A. M. (1988). Features and objects: The fourteenth Bartlett memorial lecture. *Quarterly Journal of Experimental Psychology, 40A*, 201-237.

Treisman, A. M. (1993). The perception of features and objects. In A. D. Baddeley & L. Weiskrantz (Eds.), *Attention: Awareness, selection, and control.* Oxford: Oxford University Press.

Tulving, E., & Pearlstone, Z. (1966). Availability versus accessibility of information in memory for words. *Journal of Verbal Learning & Verbal Behavior, 5*(4), 381-391.

Tulving, E. (1967). The effects of presentation and recall of material in free-recall learning. *Journal of Verbal Learning and Verbal Behavior, 6*, 175-184.

Tulving, E., & Osler, S. (1968). Effectiveness of retrieval cues in memory for words. *Journal of Experimental Psychology, 77*(4), 593-601.

Tulving, E., & Thomson, D. M. (1971). Retrieval processes in recognition memory: Effects of associative context. *Journal of Experimental Psychology, 87*(1), 116-124.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory*: Academic Press.

Tulving, E., & Thomson, D.M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80*(5), 352-373.

Tulving, E., & Watkins, M. J. (1973). Continuity between recall and recognition. *American Journal of Psychology, 86,* 739-748.

Tulving, E. (1983). *Elements of episodic memory.* London: Oxford University Press.

Tulving, E. (1984). Précis of Elements of episodic memory. *Behavioral & Brain Sciences, 7*(2), 223-268.

Tulving, E. (2000). Encoding and retrieval processes. Retrieved 6 June, 2000, from http://www.science.ca/scientists/scientistprofile.php?pID=20

Tulving, E., & Craik, F. I. M. (2000). *The Oxford handbook of memory*: Oxford University Press.

Turkle, S. (1984). *The Second Self.* New York: Simon and Schuster.

Underwood, G. M. (1974). The effect of extended shadowing practice. *Quarterly Journal of Experimental Psychology, 26*, 368-372.

Usher, M., & Niebur, E. (1996). Modeling the temporal dynamics of IT neurons in visual search: A mechanism for top-down selective attention. *Journal of Cognitive Neuroscience, 8*(4), 311-327.

Wark, M. (1994). The video game as an emergent media form. *Media Information Australia, 71*, 21-30.

Watson, J. (1987). Princess! In M. McLeod & L. Wevers (Eds.), *Women's work: contemporary short stories by New Zealand women*. (pp. 199 -203). Auckland, N.Z: Oxford University Press.

Welch, R. L., Huston-Stein, A., Wright, J.C., & Plehal, R. (1979). Subtle sex-role cues in children's commercials. *Journal of Communication, 29*, 202-209.

Wickens, C. D. (1984). Processing resources in attention. In R. Parasuraman & D. R. Davies (Eds.), *Varieties of Attention*. Orlando, FL: Academic Press.

Wolfe, J. M. (1992). The parallel guidance of visual attention. *Current Directions in Psychological Science, 1*(4), 124-128.

Wood, M. (1989). Sudden fiction international: sixty short-short stories. In R. Shapard & J. Thomas (Eds.), (pp. 154 - 157). London: Paladin.

GLOSSARY

Video game - the terms 'video game,' 'computer game,' and 'interactive game' have been used interchangeably in research literature. In general, video games refer to games that are playing on a game system such as Nintendo or Playstation and usually require more complex problem-solving and strategy compared to arcade games.

Attention - a concentration of mental activity; a matter of extracting meaning from the world, and perceiving the significance of events

Divided Attention/Dual-Attention – these terms are used interchangeably in research literature. They refer to the ability to attend and process information from more than one source simultaneously.

Encoding – a subprocess that perceives sources of new information, operates on the information using stored knowledge, and enters data into memory.

Retrieval – is a joint product of information stored in the past and information present in the immediate cognitive environment.

Dual-Attention Task – a task that requires one to divide attention, simultaneously attend to two or more concurrent tasks, and respond to both appropriately and/or efficiently. If it involves two tasks, one is usually referred to as the primary task and the other as the secondary task.

Memory cost - refers to the drop in word recall in the dual attention condition compared to the full attention condition.

RT cost - refers to the slowing of RT in the divided attention condition compared to single-task performance.

APPENDICES

APPENDIX A1.1

LEVEL OF EXPERIENCE IN VIDEO GAME PLAYING

Name: ______________________________

Age: ______________________________

Date of birth: ___ ___ ___
Day/Month/Year

Course enrolled in: ________________________

Determine your ability to play video games based on the following factors. Tick [ ] the category that applies to you or simply write the appropriate answer.

1. How old were you when you started playing video games?

________________ years.

2. Looking back 7 days, how much time have you spent playing video games?

______________hours.

3. Comparing yourself to the average video game player, how well can you play video games?

____	____	____	____	____	____	____
Far worse than average	Worse than average	Slightly worse than average	Average	Slightly better than average	Better than average	Far better than average

5. How frequently do you play the following types of video games?

a. Adventure

______________ hours per week.

b. Sports

______________ hours per week.

c. Puzzles

______________ hours per week.

d. Chess/cards/other board games

______________ hours per week.

e. Action

______________ hours per week.

Now assess yourself and tick whether you agree or not with the statements.

6. I am able to play well on a *new* video game.

_____	_____	_____	_____	_____	_____	_____
Strongly Agree	Agree	Slightly Agree	Not Sure	Slightly Disagree	Disagree	Strongly Disagree

7. The score I achieve in a video game will depend on my interest in the game.

_____	_____	_____	_____	_____	_____	_____
Strongly Agree	Agree	Slightly Agree	Not Sure	Slightly Disagree	Disagree	Strongly Disagree

8. I am confident while playing video games.

______	______	______	______	______	______	______
Strongly Agree	Agree	Slightly Agree	Not Sure	Slightly Disagree	Disagree	Strongly Disagree

9. I spend more time playing video games than other leisure activities such as going for walks or visiting friends, etc.

______	______	______	______	______	______	______
Strongly Agree	Agree	Slightly Agree	Not Sure	Slightly Disagree	Disagree	Strongly Disagree

10. I usually achieve a high score on video games.

______	______	______	______	______	______	______
Strongly Agree	Agree	Slightly Agree	Not Sure	Slightly Disagree	Disagree	Strongly Disagree

APPENDIX A1.2

LEVEL OF EXPERIENCE IN VIDEO GAME PLAYING (POSTTEST)

Name: ______________________________

Determine your ability to play video games based on the following factors. Tick [ ] whether you agree or not with the statements.

1. Comparing yourself to the average video game player, how well can you play video games?

____	____	____	____	____	____	____
Far worse than average	Worse than average	Slightly worse than average	Average	Slightly better than average	Better than average	Far better than average

2. I am able to play well on a *new* video game.

____	____	____	____	____	____	____
Strongly Agree	Agree	Slightly Agree	Not Sure	Slightly Disagree	Disagree	Strongly Disagree

3. The score I achieve in a video game will depend on my interest in the game.

____	____	____	____	____	____	____
Strongly Agree	Agree	Slightly Agree	Not Sure	Slightly Disagree	Disagree	Strongly Disagree

4. I am confident while playing video games.

____	____	____	____	____	____	____
Strongly Agree	Agree	Slightly Agree	Not Sure	Slightly Disagree	Disagree	Strongly Disagree

5. I spend more time playing video games than other leisure activities such as going for walks or visiting friends, etc.

______	______	______	______	______	______	______
Strongly Agree	Agree	Slightly Agree	Not Sure	Slightly Disagree	Disagree	Strongly Disagree

6. I usually achieve a high score on video games.

______	______	______	______	______	______	______
Strongly Agree	Agree	Slightly Agree	Not Sure	Slightly Disagree	Disagree	Strongly Disagree

APPENDIX B

VIDEO GAME ASSESSMENT QUESTIONNAIRE

This questionnaire evaluates how you felt about the game you played today. Please read the following statements and tick [ ] whether you agree with them or not.

1) I enjoyed playing the game.

____ Strongly Agree	____ Agree	____ Not sure	____ Disagree	____ Strongly Disagree

2) I found the game interesting.

____ Strongly Agree	____ Agree	____ Not sure	____ Disagree	____ Strongly Disagree

3) I was totally absorbed in the game.

____ Strongly Agree	____ Agree	____ Not sure	____ Disagree	____ Strongly Disagree

4) I found the game boring.

____ Strongly Agree	____ Agree	____ Not sure	____ Disagree	____ Strongly Disagree

5) I would like to play this game often.

____ Strongly Agree	____ Agree	____ Not sure	____ Disagree	____ Strongly Disagree

6) I played the game well.

___	___	___	___	___
Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree

7) I could have played better.

___	___	___	___	___
Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree

8) The game was difficult to understand.

___	___	___	___	___
Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree

9) I would like to play a similar game in the future.

___	___	___	___	___
Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree

10) I played this game *better* than other games I have played before.

___	___	___	___	___
Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree

11) I played this game *worse* than other games I have played before.

___	___	___	___	___
Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree

12) Playing video games helps me improve my skills on other activities.

_______	_______	_______	_______	_______
Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree

13) I would recommend playing video games to my friends.

_______	_______	_______	_______	_______
Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree

APPENDIX C1.1

THE SILK

'What would I do with it now?' she said. When he didn't answer, she got up, opened the wardrobe door and took the camphorwood box from the shelf where she kept her hats. 'All these years and us not daring to take a scissors to it. We should use it sometime.'

'Not on me,' he said.

'I've been thinking about your pyjamas.' She fitted a key into the brass box. 'It'd be just right.'

'A right waste, you mean,' he said. But there was no protest in his voice. In fact, it had lifted with a childish eagerness. He watched her hands as she opened the box and folded back layers of white tissue paper. Beneath them lay the blue of the silk. There was a reverent silence as she took it out and spread it under the light.

'Makes the whole room look different, doesn't it?' he said. 'I nearly forgot it looked like this.' His hands struggled free of the sheet and moved across the quilt. Gently, she picked up the blue material and poured it over his fingers.

'Aah,' he breathed, bringing it closer to his eyes. 'All the way from China.' He smiled. 'Not once did I let it out of me sight. You know that, Amy? There were those on board as would have pinched it quick as that. I kept it pinned round me middle.'

'You told me,' she said.

He rubbed the silk against the stubble of his chin. 'It's the birds that take your eye,' he said.

'At first,' said Mrs. Blackie. She ran her finger over one of the peacocks that strutted in the foreground of a continuous landscape. They were proud birds, iridescent blue, with silver threads in their tails. 'I used to like them best, but after a while you see much more, just as fine only smaller.' She pushed her glasses on to the bridge of her nose and leaned over the silk, her finger guiding her eyes over islands where waterfalls hung, eternally suspended, between pagodas and dark blue conifers, over flat lakes and tiny fishing boats, over mountains where the mists never lifted, and back again to a haughty peacock caught with one foot suspended over a rock. 'It's a work of art like you never see in this country,' she said.

Mr. Blackie inhaled the scent of camphorwood. 'Don't cut it, Amy. It's too good for an old blighter like me.' He was begging her to contradict him.

'I'll get the pattern tomorrow,' she said.

The next day, while the District Nurse was giving him his injection, she went down to the store and looked through a pile of pattern books. Appropriately, she chose a mandarin style with a high collar and piped cuffs and pockets. But Mr. Blackie, who had all his life worn striped flannel in the conventional design, looked with suspicion at the pyjama pattern and the young man who posed so easily and shamelessly on the front of the packet.

'It's the sort them teddy bear boys have,' he said.

'Nonsense,' said Mrs. Blackie.

'That's exactly what they are,' he growled. 'You're not laying me out in a lot of new-fangled nonsense.'

Mrs. Blackie put her hands on her hips. 'You'll not have any say in the matter,' she said.

'Won't I just? I'll get up and fight – see if I don't.'

The muscles at the corner of her mouth twitched uncontrollably. 'All right, Herb, if you're so set against it ---'

But now, having won the argument, he was happy. 'Get away with you, Amy. I'll get used to the idea.' He threw his lips back against his gums. 'Matter of fact, I like them fine. It's that nurse that done it. Blunt needle again.' He looked at the pattern. 'When d'you start?'

'Well –'

'This afternoon?'

'I suppose I could pin the pattern out after lunch.'

'Do it in here,' he said. 'Bring in your machine and pins and things and set them up so I can watch.'

She stood taller and tucked in her chin. 'I'm not using the machine,' she said with pride. 'Every stitch is going to be done by hand. My eyes mightn't be as good as they were once, mark you, but there's not a person on this earth can say I've lost my touch with a needle.'

His eyes closed in thought. 'How long?'

'Eh?'

'Till it's finished.'

She turned the pattern over in her hands. 'Oh – about three or four weeks. That it –if I keep it up.'

'No,' he said. 'Too long.'

'Oh Herb, you'd want a good job done, wouldn't you?' she pleaded.

'Amy – ' Almost imperceptibly, he shook his head on the pillow.

'I can do the main seams on the machine,' she said, lowering her voice.

'How long?'

'A week,' she whispered.

When she took down the silk that afternoon, he insisted on an extra pillow in spite of the warning he'd had from the doctor about lying flat with his legs propped higher than his head and shoulders.

She plumped up the pillow from her own bed and put it behind his neck; then she unrolled her tape measure along his body, legs, arms, around his chest.

'I'll have to take them in a bit,' she said, making inch-high black figures on a piece of cardboard. She took the tissue-paper pattern into the kitchen to iron flat. When she came back, he was waiting, wide-eyed with anticipation and brighter, she thought, than he'd been for many weeks.

As she laid the silk out on her bed and started pinning down the first of the pattern pieces, he described, with painstaking attempts at accuracy, the boat trip home, the stop at Hong Kong, and the merchant who had sold him the silk. 'Most of his stuff was rubbish,' he said. 'You wouldn't look twice at it. This was the only decent thing he had and even then he done me. You got to argue with these devils. Beat him down, they told me. But there was others as wanted that silk and if I hadn't made up me mind there and then I'd have lost it.' He squinted at her hands. 'What are you doing now? You just put that bit down.'

'It wasn't right,' she said, through lips closed on pins. 'I have to match it – like wallpaper.'

She lifted the pattern pieces many times before she was satisfied. Then it was evening and he was so tired that his breathing had become labored. He no longer talked. His eyes were watering from hours of concentration; the drops spilled over his red lids and soaked into the pillow.

'Go to sleep,' she said. 'Enough's enough for one day.'

'I'll see you cut it out first,' he said.

'Let's leave it till morning,' she said, and they both sensed her reluctance to put the scissors to the silk.

'Tonight,' he said.

'I'll make tea first.'

APPENDIX C1.2

PRINCESS!

For a few minutes this morning while the others were asleep I stood on the bottom step tensing every muscle in my body to listen. Yes ..... yes ......I'm sure I heard something! The echo of a whisper ..... a haunting far-away refrain......was this the Princess singing? I held my breath .... but just then a clatter from the kitchen reached my ears instead. The others were preparing breakfast.

All day we've been in the library discussing the Princess and whether or not I actually heard her singing. There is something really new and exciting about all this and yet at the same time ...... familiar, as if we'd always known it. Gareth read out a poem which says that to hear even the faintest distant echo of the Princess singing is to love her forever. He spoke and read as always, with a smile, an interested, intelligent, considering smile – he suggests that it is possible I imagined the singing. But no, I don't believe he is right, I am growing in the conviction that what I heard *was* Her song ....

I *must* hear Her again, I *must* climb further up the stairs!

If only the others wouldn't keep following me. I can't hear a thing with their inane chatter going on!

Twice today I crept to the foot of the stairs but they heard me and followed. Curious interfering meddlers!

'Shut up Darien! Shut up Fay! Shut up Old Man!' I said, 'Can't you see that I want to hear the Princess singing ......' Darien laughed insolently and flounced off with a voluptuous swish of her raven curls. Fay wept and wrung her hands saying that I needed her help if I was ever to hear the Princess.

'You wait!' The Old Man grated through his teeth. Then Gareth came out of the library and told me that I should ignore them altogether and perhaps they might give up and leave me alone ...... but then on the other hand they may well get worse in a bid for attention. Darien in particular is likely to eat more and start putting on weight. I gave up and went to set the table for the evening meal.

I heard! I heard!

There *is* a Princess!

I listened at the foot of the stairs early this morning while the others still slept.

Never could I have imagined such a beautiful sound. Just one sweet wild breath of song.

So sweet but alas so fleeting and so fragile, my listening.

There *is* a Princess! I know ...... and although I've never seen her I know how beautiful she is.

I know her breath is sweeter than the scent of violets, that only a white gown wraps her silken flesh and her fine hands and feet need no adornment and her hair falls like sunlight on rippling water and she sings forever. I am stricken with love for her, for the vision in my mind of her, for the memory of that one breath of song!

How can I meet her?

Is there some way I can attract her attention?

Gareth is still sorting through the library for any information relating to Princesses. As well as that he decided that we would keep the window open more often, in case we get some news from passers-by. Gareth says I will have to get further up the stairs if I want to hear Her better.

Fay has taken it upon herself to read out to me a book called *Purity of Purpose*. She has frequent fits of weeping during which she insists that I will never meet the Princess as long as Darien lives with us. Darien has been strangely quiet these last few days.... but she seems to be putting on weight. I wouldn't be surprised if she's been sneaking stuff from the kitchen while the rest of us talk about the Princess.

She lives, she lives forever!

The Princess, I'm so happy to know that she is there in our attic!

Oh black despair!

Will I *never* hear Her again?

Today I set foot on the first creaky step of the stairs and stood for a minute there holding my breath ...... then another step, another minute's breathless wait.....

Yet another step, my fingers gripped the dusty banister....... All was silent.

'Princess ...... Princess .... I love you.' I called.

When Darien, Darien that evil, cruel, malevolent wretch! She let the kitchen door slam causing the whole house to shake.

How I despise her!

She spoilt any chance I had of hearing the Princess that day. Then Fay came rushing out of the library and began to scold her. Of course Gareth tried to placate them both.

I'm beginning to see how little control Gareth has over those others. As for the Old Man, I think Gareth is actually scared of him.

I know I've relied on Gareth for years and I know he's doing his level best to help me meet the Princess.

But I must say I'm getting sick of the sound of his voice. I can see that if I want to meet the Princess I will have to dodge them ALL.

I know one day I'll see her!

She lives! The radiance of her beauty imprisoned in her attic.

I want to set her free to rule us all.

I know she is there and that she is more beautiful than the first early morning ray of sunlight shining through the window. Her song sweeter than the first bird's song at dawn.

APPENDIX C1.3

DISAPPEARING

So I went back. And floated again. My arms came around and the groan of the water made the tight blondes smirk but I heard Good that's the crawl that's it in fragments from the redhead when I lifted my face. Through earplugs I heard her skinny voice. She was happy that I was floating and moving too.

Lettie stopped the lessons and read to me things out of magazines. You have to swim a lot to lose weight. You have to stop eating too. Forget cake and ice cream. Doritos are out. I'm not doing it for that I told her but she wouldn't believe me. She couldn't imagine.

Looking down that shaft of water I know I won't fall. The water shimmers and eases up and down, the heft of me doesn't matter I float anyway.

He says it makes not difference I look the same. But I'm not the same. I can hold myself up in deep water. I can move my arms and feet and the water goes behind me, the wall comes closer. I can look down twelve feet to a cold slab of tile and not be afraid. It makes a difference I tell him. Better believe it mister.

APPENDIX C2.1

COMPREHENSION QUESTIONS FOR *THE SILK*

Read each statement and choose the correct answer by ticking ( )'True' or 'False'.

1. Mrs. Blackie wanted to make pyjamas from the silk cloth.

True False

2. The silk material was red in colour.

True False

3. Mr. and Mrs. Blackie thought that the silk cloth was beautiful.

True False

4. Mrs. Blackie took an injection from the District Nurse.

True False

5. Mrs. Blackie chose a common pattern to stitch something for Mr. Blackie.

True False

6. Mr. Blackie was excited about what Mrs. Blackie was going to stitch for him.

True False

7. Mrs. Blackie wanted to use the sewing machine to stitch the cloth.

True False

8. Mr. Blackie had bought the cloth from Hong Kong.

True False

9. Mr. Blackie's eyes were watering after hours of concentration on the cloth that Mrs. Blackie was stitching.

True False

10. Mr. Blackie wanted to buy several other things from the merchant who sold him the silk.

True False

APPENDIX C2.2

COMPREHENSION QUESTIONS FOR *PRINCESS*!

Read each statement and choose the correct answer by ticking ( )'True' or 'False'.

1. The Princess could be heard singing.

   True False

2. Gareth read out a poem which says to hear the Princess singing is to love her forever.

   True False

3. The Princess was thought to be downstairs.

   True False

4. The Old Man said that his help was needed to hear the Princess singing.

   True False

5. Darien liked to eat more than others.

   True False

6. The Princess sang a horrible song.

   True False

7. Fay cried and said that they would not be able to meet the Princess and long as Darien lived with them.

   True False

8. The author of the story is eager to meet the Princess.

   True False

9. Gareth was happy that the author could not meet the Princess.

True False

10. The Princess is described as being very beautiful.

True False

APPENDIX C2.3

COMPREHENSION QUESTIONS FOR *DISAPPEARING*

Read each statement and choose the correct answer by ticking ( )'True' or 'False'.

1. The author of the story received encouragement to swim well.

   True False

2. Lettie said that swimming did not help in losing weight.

   True False

3. The author of the story was able to swim quite well.

   True False

APPENDIX D1.1

LIST OF WORDS FOR DICTATION DURING – THE SILK

1. School
2. Number
3. Craft
4. Three
5. Water
6. Room
7. Program
8. Night
9. System
10. White
11. City
12. Crystal
13. Church
14. Human
15. Insects
16. Family
17. Body
18. Chart
19. Country
20. Money
21. Name
22. Question
23. College
24. Tie
25. Service
26. Boy
27. Drinks
28. Hen
29. Union
30. West
31. Mother
32. Party
33. Nature
34. Soap
35. Face
36. Young
37. Things
38. Study
39. Light

40. Shell
41. Public
42. Office
43. Person
44. Nuts
45. Valves
46. Land
47. Skirt
48. Cream
49. Colour
50. Short
51. Voice
52. Clock
53. Girl
54. South
55. Club
56. Friends
57. Paper
58. Police
59. Class
60. Jungle
61. Earth
62. Food
63. River
64. Blue
65. Parks
66. Sauce
67. Play
68. Summer
69. List
70. Tax
71. Lost
72. Age
73. Heart
74. Students
75. Final
76. Job
77. Woman
78. Stage
79. Value
80. Rate
81. Degree
82. Science

83. Horse
84. Window
85. Love

APPENDIX D1.2

LIST OF WORDS FOR DICTATION DURING – PRINCESS!

1. Women
2. Lung
3. Taxi
4. Place
5. Members
6. Bees
7. Cop
8. Trains
9. Force
10. Research
11. Drums
12. Subject
13. Plan
14. Reward
15. Morning
16. Need
17. Action
18. Lawn
19. Field
20. Car
21. Onion
22. Lines
23. Road
24. Brown
25. Trade
26. Letter
27. Ticket
28. Near
29. Cost
30. Size
31. Easy
32. Resume
33. Staff
34. Month
35. Bed
36. Hotel
37. Health
38. Choice
39. Plant

40. Potato
41. Idea
42. Wife
43. Hard
44. Fine
45. Stand
46. March
47. Radio
48. Rope
49. Teeth
50. Pool
51. Feed
52. Types
53. Press
54. Doctor
55. Green
56. Farm
57. Seven
58. News
59. Heat
60. Park
61. Lord
62. Project
63. Station
64. Pattern
65. King
66. Learn

APPENDIX D1.3

LIST OF WORDS FOR DICTATION DURING – DISAPPEARING

1. Cat
2. House
3. Cabin
4. Word
5. Flower
6. Group
7. Child
8. Table
9. Fire
10. Space
11. World
12. List
13. Book
14. Belt
15. Lift
16. Men
17. Lock
18. Case
19. Street
20. Story
21. Girls
22. Plates
23. Town
24. Sheep
25. Answer

APPENDIX E1.1

LIST OF WORDS FOR FREE RECALL - 1

1. Gem
2. Copper
3. Tiger
4. Husband
5. Desk
6. Mixer
7. Velvet
8. Peach
9. Journal
10. Foot
11. Champagne
12. Tent

APPENDIX E1.2

LIST OF WORDS FOR FREE RECALL - 2

1. Paper
2. Brick
3. Lake
4. Shoes
5. Parrot
6. Violin
7. Soccer
8. Pepsi
9. Lettuce
10. Game
11. Truck
12. Spider

APPENDIX E1.3

LIST OF WORDS FOR FREE RECALL – 3

1. Essay
2. Daughter
3. Pig
4. Cup
5. Mouth
6. Lamp
7. Hut
8. Cherry
9. Vanilla
10. Juice
11. Bike
12. Slippers

APPENDIX E4.1

LIST OF WORDS FOR FREE RECALL – 4

1. Daisy
2. Trout
3. Lion
4. Purple
5. Dish
6. Sofa
7. Neck
8. Plum
9. Alcohol
10. Nurse
11. Spices
12. Hill

APPENDIX E1.5

LIST OF WORDS FOR FREE RECALL - 5

1. Mountain
2. Coat
3. Skirt
4. Opera
5. Potato
6. Cold
7. Shark
8. Pearl
9. Brother
10. Letter
11. Horse
12. Fork

APPENDIX E1.6

LIST OF WORDS FOR FREE RECALL - 6

1. Ant
2. Rose
3. Orange
4. Tuna
5. Mother
6. Silver
7. Book
8. Dog
9. Black
10. Chocolate
11. Water
12. Teacher

APPENDIX E1.7

LIST OF WORDS FOR FREE RECALL - 7

1. Hand
2. Garlic
3. Coat
4. Table
5. Grape
6. Home
7. Play
8. Vodka
9. Storm
10. Roof
11. Crow
12. Uncle

APPENDIX E1.8

LIST OF WORDS FOR FREE RECALL - 8

1. Silk
2. Television
3. Legs
4. Hotel
5. Sugar
6. Pants
7. Train
8. Spinach
9. Goldfish
10. Tulip
11. Ruby
12. Aunt

APPENDIX E2.1

LIST OF WORDS FOR FREE RECALL - 9

1. Rock
2. Tennis
3. Socks
4. Wall
5. Piano
6. Tea
7. Bus
8. Carrot
9. Novel
10. Wool

APPENDIX E2.2

LIST OF WORDS FOR FREE RECALL - 10

1. Sister
2. Newspaper
3. Head
4. Sheep
5. Glass
6. Pink
7. Bed
8. Banana
9. Beer
10. Oil

APPENDIX E2.3

LIST OF WORDS FOR FREE RECALL - 11

1. River
2. Football
3. Shirt
4. Sandals
5. Pigeon
6. Coke
7. Car
8. Fly
9. Doll
10. Tomato

APPENDIX E2.4

LIST OF WORDS FOR FREE RECALL – 12

1. Diamond
2. Father
3. Gold
4. Cat
5. Cotton
6. Spoon
7. Chair
8. Finger
9. Apple
10. House

APPENDIX F1.1

LIST OF WORDS FOR CUED RECALL – 1

1. Parents – Wagon
2. Engine – Dust
3. Cars - Plane
4. Pepper – Rooms
5. Guitar – Bat
6. Camp – Seat
7. Page - Letters
8. Doctors - Pot
9. Ham - Books
10. Shop - Bone
11. Signal – Birds
12. Ice - Bar

APPENDIX F1.2

LIST OF WORDS FOR CUED RECALL – 2

1. Eggs – Bell
2. Fish – Dogs
3. Coat – Universe
4. Root – Cow
5. Muscles – Hills
6. Jacket – Candle
7. Studio – Fence
8. Belt – Mud
9. Golf - Cap
10. Ocean - Soldier
11. Stars – Paint
12. Rain - Mail

APPENDIX F1.3

LIST OF WORDS FOR CUED RECALL – 3

1. Sweet – Stomach
2. Wine – Snow
3. Disk - Pond
4. Object – Glass
5. Homes – Beach
6. Beard - Card
7. Honey - Fan
8. File – Dishes
9. Brother – Museum
10. Estate – Farmers
11. Roads – Fashion
12. Frame – Foot

APPENDIX F1.4

LIST OF WORDS FOR CUED RECALL– 4

1. Faces – Clothes
2. Horses – Pen
3. Poems – Camera
4. Model – Coffee
5. Bottle – Opal
6. Dollar – Lemon
7. Waves – Chest
8. Papers – Rice
9. Truck – Notes
10. Sandals - Prince
11. Basket – Bible
12. Chair - Wings

APPENDIX F1.5

LIST OF WORDS FOR CUED RECALL – 5

1. Rain – Aircraft
2. Watch – Phone
3. Village - Church
4. Pictures – Cousin
5. Garage - Pipe
6. Builder - Jail
7. Meal – Shorts
8. Sand – Stable
9. Mirror – Chin
10. Dancer - Desert
11. Dollars – Van
12. Factory - Boots

APPENDIX F1.6

LIST OF WORDS FOR CUED RECALL – 6

1. Flower – Prize
2. Bus – Branch
3. Net – Tea
4. Powder – Cloud
5. Child - Sink
6. Bread – Tables
7. Seed – Tape
8. Cards – Crown
9. Offices – Shoes
10. Brain - Fluid
11. Liquor - Mustard
12. Mars – Movie

APPENDIX F1.7

LIST OF WORDS FOR CUED RECALL – 7

1. Butter – Drugs
2. Chips - Shops
3. Partner - Cottage
4. Campus – Bone
5. Pages – Tools
6. Sugar – Keys
7. Films - Candy
8. Vehicle – Presents
9. Smoke – String
10. Table – Fountain
11. Book - Tap
12. Collar - Flag

APPENDIX F1.8

LIST OF WORDS FOR CUED RECALL – 8

1. Novel – Farm
2. Dance - Pin
3. Pan - Pottery
4. Stone - Soup
5. Moon – Professor
6. Songs – Tray
7. Gown - Jeep
8. Queen – Blonde
9. Beer – Gift
10. Bride – Pool
11. Pencil – Polish
12. Theatre - Calendar

APPENDIX F2.1

LIST OF WORDS FOR CUED RECALL– 9

1. Bank – Wine
2. Teacher – Boat
3. Rock – Box
4. Lady – Chain
5. Ships – Wheel
6. Kids – Baseball
7. Chair – Milk
8. Tubes - Tail
9. Football – Sky
10. Garden – Peas

APPENDIX F2.2

LIST OF WORDS FOR CUED RECALL – 10

1. Fruit – Metal
2. Stick - Cash
3. Gate – Drawings
4. Bag – Clouds
5. Skin – Cup
6. Legs – Yellow
7. Female – Crowd
8. Hat – Grass
9. Bench – Hearts
10. Palace – Chicken

APPENDIX F2.3

LIST OF WORDS FOR CUED RECALL – 11

1. Tissue – Salt
2. Dirt – Desk
3. Nest – Sheet
4. Brush – Tooth
5. Airport – Meat
6. Animal – Pink
7. Dress – Library
8. Message – Drum
9. Finger – Baker
10. Ring – Ballet

APPENDIX F2.4

LIST OF WORDS FOR CUED RECALL – 12

1. Flowers – Windows
2. Driver – Player
3. Tree – Games
4. Soil – Weather
5. Forest – Colours
6. Notice – Fund
7. Markets - Cycle
8. Piano – Cotton
9. Cloth – Pilot
10. Baby - Flight

APPENDIX G

SAMPLE DISTRACTOR TASK -

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Victoria University of Technology

HRETH FOA-0030/98
St Albans Campus

APPENDIX H

Memorandum

ETH0116

VICTORIA UNIVERSITY OF TECHNOLOGY

TO:	Dr Keis Ohtsuka Department of Psychology
FROM:	Ms Deb Tyler Chair Faculty of Arts Human Research Ethics Committee
DATE:	4 November 1998
SUBJECT:	**HRETH.FOA.0030/98 involving human subjects**

As per the Committee's letter of 26 October the Chair of the Faculty of Arts Human Research Ethics Committee considered the response to application for project:

Video Game Playing: Its Effects on Divided Attention, Encoding and Retrieval Processes of Human Memory

It was resolved to approve application HRETH.FOA.0030/98 from 15 November 1998 to 15 October 1999.

[redacted]

Pr **Ms Deb Tyler**

Campuses at
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St Albans, Werribee

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McKechnie Street
St Albans

St Albans Campus

APPENDIX I

RES0351

ID NO: 9717016

VICTORIA UNIVERSITY OF TECHNOLOGY

29 October 1998

Ms Lata Satyen
21/4 The Gables
Sunshine 3020

Dear Lata

I am pleased to inform you that at its meeting on 23 October 1998 the Faculty of Arts Research and Postgraduate Studies Committee agreed to **recommend** to the Committee for Postgraduate Studies that you be admitted to candidature for the degree of Doctor of Philosophy.

The Committee for Postgraduate Studies will consider your Application for Doctoral Candidature at its next meeting on 11 November 1998.

The Committee granted you a total budget of $1,174.

I would like to take this opportunity to wish you the best in your studies.

If you have any queries about your candidature please do not hesitate to contact me on 9365 2689.

Yours sincerely

[redacted]
Faculty of Arts
Research & Postgraduate Studies Committee

cc: Dr D Bruck – Head of Department
Dr K Ohtsuka – Principal Supervisor

Campuses at City,
Footscray, Melton,

APPENDIX J

VICTORIA UNIVERSITY OF TECHNOLOGY

Consent Form for Participants Involved in Research

INFORMATION TO PARTICIPANTS:

Thank you for volunteering to be a part of the study which looks at video game playing and its effects on attention and memory. You will be required to perform some memory tests and then may have to play the video game for about one hour or six hours. You will also be asked to complete a few questionnaires and do some simple tasks such as reading short stories and remembering some words that I will read out to you. The study will be conducted at the Department of Psychology, Victoria University of Technology, Werribee Campus. Your participation is voluntary, and if you feel uncomfortable at any stage of the study, you are free to withdraw your participation from the study, and in doing so, you will not be put to any disadvantage. As a result of playing the video games, you may experience slight fatigue of the eyes and hands, however, in order to overcome this, you will be allowed to have a break in between each session.

CERTIFICATION BY SUBJECT

I, ...
certify that I am at least 17 years old and that I am voluntarily giving my consent to participate in the experiment entitled: Video Game Playing: Its Effects on Divided Attention, Encoding and Retrieval Processes of Human Memory, which will be conducted at Victoria University of Technology by Miss Lata Satyen.
I certify that the objectives of the experiment, together with any risks associated with the procedures of the experiment, have been fully explained to me by Miss Lata Satyen and, that I freely consent to participate in the experiment involving the use of these procedures.
I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this experiment at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the information I provide will be kept confidential.

Signed: .... Date: ....

Any queries about your participation in this project may be directed to the researcher (Name: Miss Lata Satyen - ph: 9216 8025). If you have any queries or complaints about the way you have been treated, you may contact the Secretary, University Human Research Ethics Committee, Victoria University of Technology, PO Box 14428 Melbourne City, MC - 8001 (telephone no: 03-9688 4710).

APPENDIX K1.1

Table K1.1

Covariate results for correct word recall in the Free Recall tasks performed under divided attention conditions for the short-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	F	df	p
DA-FA	DA-FA	.680	1, 20	>.05
	FA-DA	.993	1,20	> .05
	DA-DA	2.565	1,20	> .05
FA-DA	DA-FA	5.409	1,20	.031*
	FA-DA	2.083	1,20	> .05
	DA-DA	10.262	1,20	.004**
DA-DA	DA-FA	.086	1,20	> .05
	FA-DA	.876	1,20	> .05
	DA-DA	4.399	1,20	> .05

* denotes significance at the .05 level; ** denotes significance at the .01 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

APPENDIX K1.2

Table K1.2

Covariate results for RT accuracy in the Free Recall tasks performed under divided attention conditions for the short-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	F	df	p
DA-FA	DA-FA	27.491	1, 19	.001**
	FA-DA	.370	1,19	> .05
	DA-DA (E)	40.230	1,19	.001**
	DA-DA (R)	5.091	1,19	.036*
FA-DA	DA-FA	.000	1,19	> .05
	FA-DA	.006	1,19	> .05
	DA-DA (E)	.030	1,19	> .05
	DA-DA (R)	.563	1,19	> .05
DA-DA (E)	DA-FA	2.159	1,19	> .05
	FA-DA	.074	1,19	> .05
	DA-DA (E)	.228	1,19	> .05
	DA-DA (R)	2.530	1,19	> .05
DA-DA (R)	DA-FA	2.389	1,19	> .05
	FA-DA	16.162	1,19	.001**
	DA-DA (E)	2.688	1,19	> .05
	DA-DA (R)	2.590	1,19	> .05

* denotes significance at the .05 level; ** denotes significance at the .01 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

APPENDIX L1.1

Table L1.1

Covariate results for correct word recall in the Cued Recall tasks performed under divided attention conditions for the short-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	*F*	df	*p*
DA-FA	DA-FA	3.850	1, 20	>.05
	FA-DA	.134	1,20	> .05
	DA-DA	.001	1,20	> .05
FA-DA	DA-FA	1.334	1,20	> .05
	FA-DA	.072	1,20	> .05
	DA-DA	2.170	1,20	> .05
DA-DA	DA-FA	3.618	1,20	> .05
	FA-DA	6.818	1,20	.017*
	DA-DA	5.336	1,20	.032*

* denotes significance at the .05 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

APPENDIX L1.2

Table L1.2

Covariate results for RT accuracy in the Cued Recall tasks performed under divided attention conditions for the short-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	*F*	df	*p*
DA-FA	DA-FA	.350	1, 19	> .05
	FA-DA	1.231	1,19	> .05
	DA-DA (E)	2.447	1,19	> .05
	DA-DA (R)	.226	1,19	> .05
FA-DA	DA-FA	5.640	1,19	.028*
	FA-DA	.082	1,19	> .05
	DA-DA (E)	.004	1,19	> .05
	DA-DA (R)	15.262	1,19	.001**
DA-DA (E)	DA-FA	18.120	1,19	.001**
	FA-DA	.598	1,19	> .05
	DA-DA (E)	6.052	1,19	.024*
	DA-DA (R)	.006	1,19	> .05
DA-DA (R)	DA-FA	5.035	1,19	.037*
	FA-DA	1.641	1,19	> .05
	DA-DA (E)	.000	1,19	> .05
	DA-DA (R)	1.003	1,19	> .05

* denotes significance at the .05 level; ** denotes significance at the .01 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

APPENDIX M1.1

Table M1.1

Covariate results for correct word recall in the Free Recall tasks performed under divided attention conditions for the long-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	*F*	df	*p*
DA-FA	DA-FA	.859	1, 20	>.05
	FA-DA	.039	1,20	> .05
	DA-DA	.289	1,20	> .05
FA-DA	DA-FA	.538	1,20	> .05
	FA-DA	8.008	1,20	.010**
	DA-DA	4.395	1,20	> .05
DA-DA	DA-FA	2.068	1,20	> .05
	FA-DA	.185	1,20	> .05
	DA-DA	10.962	1,20	.003**

** denotes significance at the .01 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

APPENDIX M1.2

Table M1.2

Covariate results for RT accuracy in the Free Recall tasks performed under divided attention conditions for the long-term training group (N = 25)

Covariate	Dependent variable	F	df	p
DA-FA	DA-FA	.076	1, 19	> .05
	FA-DA	.127	1,19	> .05
	DA-DA (E)	.737	1,19	> .05
	DA-DA (R)	.198	1,19	> .05
FA-DA	DA-FA	.119	1,19	> .05
	FA-DA	.036	1,19	> .05
	DA-DA (E)	3.497	1,19	> .05
	DA-DA (R)	1.075	1,19	> .05
DA-DA (E)	DA-FA	2.011	1,19	> .05
	FA-DA	.188	1,19	> .05
	DA-DA (E)	24.069	1,19	.000**
	DA-DA (R)	2.287	1,19	> .05
DA-DA (R)	DA-FA	4.780	1,19	.042*
	FA-DA	20.204	1,19	.000**
	DA-DA (E)	.001	1,19	> .05
	DA-DA (R)	15.757	1,19	.001**

* denotes significance at the .05 level; ** denotes significance at the .01 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

APPENDIX N1.1

Table N1.1

Covariate results for correct word recall in the Cued Recall tasks performed under divided attention conditions for the long-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	*F*	df	*p*
DA-FA	DA-FA	4.392	1, 20	>.05
	FA-DA	.005	1,20	> .05
	DA-DA	2.548	1,20	> .05
FA-DA	DA-FA	.256	1,20	> .05
	FA-DA	1.194	1,20	> .05
	DA-DA	.014	1,20	> .05
DA-DA	DA-FA	1.013	1,20	> .05
	FA-DA	4.747	1,20	.041*
	DA-DA	5.706	1,20	.027*

* denotes significance at the .05 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (Divided attention at encoding; divided attention at retrieval)

APPENDIX N1.2

Table N1.2

Covariate results for RT accuracy in the Cued Recall tasks performed under divided attention conditions for the long-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	*F*	df	*p*
DA-FA	DA-FA	17.296	1, 19	.001**
	FA-DA	4.437	1,19	> .05
	DA-DA (E)	1.842	1,19	> .05
	DA-DA (R)	9.891	1,19	.005**
FA-DA	DA-FA	3.737	1,19	> .05
	FA-DA	9.596	1,19	.006**
	DA-DA (E)	2.518	1,19	> .05
	DA-DA (R)	14.546	1,19	.001**
DA-DA (E)	DA-FA	.000	1,19	> .05
	FA-DA	.491	1,19	> .05
	DA-DA (E)	9.202	1,19	.007**
	DA-DA (R)	.258	1,19	> .05
DA-DA (R)	DA-FA	4.433	1,19	> .05
	FA-DA	.307	1,19	> .05
	DA-DA (E)	.373	1,19	> .05
	DA-DA (R)	.195	1,19	> .05

* denotes significance at the .05 level; ** denotes significance at the .01 level

Note:
DA-FA (Divided attention at encoding; full attention at retrieval)
FA-DA (Full attention at encoding; divided attention at retrieval)
DA-DA (E) (Divided attention at encoding; divided attention at retrieval – RT measurement at Encoding)
DA-DA (R) (Divided attention at encoding; divided attention at retrieval – RT measurement at Retrieval)

APPENDIX O1.1

Table O1.1

Covariate results for memory costs in the Free Recall tasks for the short-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	*F*	df	*p*
DAFA - FAFA	DAFA-FAFA	.374	1, 20	>.05
	FADA-FAFA	.900	1,20	> .05
	DADA-FAFA	.530	1,20	> .05
FADA - FAFA	DAFA-FAFA	.589	1,20	> .05
	FADA-FAFA	.038	1,20	> .05
	DADA-FAFA	.259	1,20	> .05
DADA - FAFA	DAFA-FAFA	.266	1,20	> .05
	FADA-FAFA	.289	1,20	> .05
	DADA-FAFA	.210	1,20	> .05

Note:

DAFA - FAFA (Memory performance of Divided attention at encoding, Full attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (Memory performance of Full attention at encoding, Divided attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

DA-DA – FAFA (Memory performance of Divided attention at encoding and retrieval task minus memory performance with Full Attention at encoding and retrieval)

APPENDIX O1.2

Table O1.2

Covariate results for Reaction Time costs in the Free Recall tasks for the long-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	F	df	p
DAFA -FAFA	DAFA-FAFA	24.897	1, 19	.001**
	FADA-FAFA	.591	1,19	> .05
	DADA (E) –FAFA	68.779	1,19	.000**
	DADA (R) -FAFA	1.642	1,19	> .05
FADA -FAFA	DAFA-FAFA	1.785	1,19	> .05
	FADA-FAFA	.395	1,19	> .05
	DADA (E)-FAFA	2.299	1,19	> .05
	DADA (R)-FAFA	1.758	1,19	> .05
DADA (E)–FAFA	DAFA-FAFA	2.522	1,19	> .05
	FADA-FAFA	.020	1,19	> .05
	DADA (E) –FAFA	.352	1,19	> .05
	DADA (R) – FAFA	1.153	1,19	> .05
DADA (R)-FAFA	DAFA-FAFA	6.967	1,19	.016*
	FADA-FAFA	14.279	1,19	.001**
	DADA (E)-FAFA	11.478	1,19	.003**
	DADA (R)-FAFA	.684	1,19	> .05

* denotes significance at the .05 level; ** denotes significance at the .01 level

Note:

DAFA – FAFA (RT task performance with Divided attention at encoding, Full attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (RT task performance with Full attention at encoding, Divided attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (E) - FAFA (RT task performance at Encoding with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (R) - FAFA (RT task performance at Retrieval with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

APPENDIX P1.1

Table P1.1

Covariate results for memory costs in the Cued Recall tasks for the short-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	*F*	df	*p*
DAFA - FAFA	DAFA-FAFA	.043	1, 20	>.05
	FADA-FAFA	1.192	1,20	> .05
	DADA-FAFA	1.679	1,20	> .05
FADA - FAFA	DAFA-FAFA	.000	1,20	> .05
	FADA-FAFA	.885	1,20	> .05
	DADA-FAFA	.042	1,20	> .05
DADA - FAFA	DAFA-FAFA	.749	1,20	> .05
	FADA-FAFA	2.035	1,20	> .05
	DADA-FAFA	1.693	1,20	> .05

Note:

DAFA - FAFA (Memory performance of Divided attention at encoding, Full attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (Memory performance of Full attention at encoding, Divided attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

DA-DA – FAFA (Memory performance of Divided attention at encoding and retrieval task minus memory performance with Full Attention at encoding and retrieval)

APPENDIX P1.2

Table P1.2

Covariate results for Reaction Time costs in the Cued Recall tasks for the short-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	F	df	p
DAFA -FAFA	DAFA-FAFA	.066	1, 19	>.05
	FADA-FAFA	.541	1,19	> .05
	DADA (E) –FAFA	.137	1,19	> .05
	DADA (R) -FAFA	.023	1,19	> .05
FADA -FAFA	DAFA-FAFA	5.748	1,19	.027*
	FADA-FAFA	.027	1,19	> .05
	DADA (E)-FAFA	1.607	1,19	> .05
	DADA (R)-FAFA	5.132	1,19	.035*
DADA (E)–FAFA	DAFA-FAFA	10.252	1,19	.005**
	FADA-FAFA	.076	1,19	> .05
	DADA (E) –FAFA	1.349	1,19	> .05
	DADA (R) – FAFA	.490	1,19	> .05
DADA (R)-FAFA	DAFA-FAFA	7.410	1,19	.014**
	FADA-FAFA	2.955	1,19	> .05
	DADA (E)-FAFA	1.969	1,19	> .05
	DADA (R)-FAFA	.001	1,19	> .05

* denotes significance at the .05 level; ** denotes significance at the .01 level

Note:

DAFA – FAFA (RT task performance with Divided attention at encoding, Full attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (RT task performance with Full attention at encoding, Divided attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (E) - FAFA (RT task performance at Encoding with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (R) - FAFA (RT task performance at Retrieval with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

APPENDIX Q1.1

Table Q1.1

Covariate results for memory costs in the Free Recall tasks for the long-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	F	df	p
DAFA - FAFA	DAFA-FAFA	.193	1, 20	>.05
	FADA-FAFA	.972	1,20	> .05
	DADA-FAFA	1.741	1,20	> .05
FADA - FAFA	DAFA-FAFA	2.091	1,20	> .05
	FADA-FAFA	.001	1,20	> .05
	DADA-FAFA	1.038	1,20	> .05
DADA - FAFA	DAFA-FAFA	.987	1,20	> .05
	FADA-FAFA	.458	1,20	> .05
	DADA-FAFA	4.148	1,20	> .05

Note:

DAFA - FAFA (Memory performance of Divided attention at encoding, Full attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (Memory performance of Full attention at encoding, Divided attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

DA-DA – FAFA (Memory performance of Divided attention at encoding and retrieval task minus memory performance with Full Attention at encoding and retrieval)

APPENDIX Q1.2

Table Q1.2

Covariate results for Reaction Time costs in the Free Recall tasks for the long-term training group ($N = 25$)

Covariate	Dependent variable (posttests)	F	df	p
DAFA -FAFA	DAFA-FAFA	.698	1, 18	>.05
	FADA-FAFA	.089	1,18	> .05
	DADA (E) –FAFA	1.247	1,18	> .05
	DADA (R) -FAFA	.440	1,18	> .05
FADA -FAFA	DAFA-FAFA	.666	1,18	> .05
	FADA-FAFA	.313	1,18	> .05
	DADA (E)-FAFA	.001	1,18	> .05
	DADA (R)-FAFA	.617	1,18	> .05
DADA (E)–FAFA	DAFA-FAFA	1.156	1,18	> .05
	FADA-FAFA	.889	1,18	> .05
	DADA (E) –FAFA	.908	1,18	> .05
	DADA (R) – FAFA	.624	1,18	> .05
DADA (R)-FAFA	DAFA-FAFA	7.167	1,18	.015*
	FADA-FAFA	20.633	1,18	.000**
	DADA (E)-FAFA	.437	1,18	> .05
	DADA (R)-FAFA	10.653	1,18	.004**

* denotes significance at the .05 level; ** denotes significance at the .01 level

Note:

DAFA – FAFA	(RT task performance with Divided attention at encoding, Full attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)
FA-DA - FAFA	(RT task performance with Full attention at encoding, Divided attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)
DA-DA (E) - FAFA	(RT task performance at Encoding with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)
DA-DA (R) - FAFA	(RT task performance at Retrieval with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

APPENDIX R1.1

Table R1.1

Covariate results for memory costs in the Cued Recall tasks for the long-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	*F*	df	*p*
DAFA - FAFA	DAFA-FAFA	3.331	1, 20	>.05
	FADA-FAFA	1.240	1,20	> .05
	DADA-FAFA	.635	1,20	> .05
FADA - FAFA	DAFA-FAFA	.236	1,20	> .05
	FADA-FAFA	.146	1,20	> .05
	DADA-FAFA	.178	1,20	> .05
DADA - FAFA	DAFA-FAFA	1.302	1,20	> .05
	FADA-FAFA	3.907	1,20	> .05
	DADA-FAFA	5.448	1,20	.030*

* denotes significance at the .05 level

Note:

DAFA - FAFA (Memory performance of Divided attention at encoding, Full attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (Memory performance of Full attention at encoding, Divided attention at retrieval task minus memory performance with Full Attention at encoding and retrieval)

DA-DA – FAFA (Memory performance of Divided attention at encoding and retrieval task minus memory performance with Full Attention at encoding and retrieval)

APPENDIX R1.2

Table R1.2

Covariate results for Reaction Time costs in the Cued Recall tasks for the long-term training group ($N = 25$)

Covariate	Dependent variable (posttest)	F	df	p
DAFA -FAFA	DAFA-FAFA	1.330	1, 18	>.05
	FADA-FAFA	.534	1,18	> .05
	DADA (E) –FAFA	.029	1,18	> .05
	DADA (R) -FAFA	1.152	1,18	> .05
FADA -FAFA	DAFA-FAFA	5.723	1,18	.028*
	FADA-FAFA	14.565	1,18	.001**
	DADA (E)-FAFA	5.541	1,18	.030*
	DADA (R)-FAFA	20.315	1,18	.000**
DADA (E)–FAFA	DAFA-FAFA	.511	1,18	> .05
	FADA-FAFA	.472	1,18	> .05
	DADA (E) –FAFA	8.222	1,18	.010**
	DADA (R) – FAFA	.040	1,18	> .05
DADA (R)-FAFA	DAFA-FAFA	3.784	1,18	> .05
	FADA-FAFA	1.123	1,18	> .05
	DADA (E)-FAFA	1.804	1,18	> .05
	DADA (R)-FAFA	.828	1,18	> .05

* denotes significance at the .05 level; ** denotes significance at the .01 level

Note:

DAFA – FAFA (RT task performance with Divided attention at encoding, Full attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

FA-DA - FAFA (RT task performance with Full attention at encoding, Divided attention at retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (E) - FAFA (RT task performance at Encoding with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)

DA-DA (R) - FAFA (RT task performance at Retrieval with Divided attention at encoding and retrieval minus RT task performance with Full Attention at encoding and retrieval)