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EFFECTS OF COMPUTER GAME PLAYING ON SPATIAL SKILLS

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ABSTRACT

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This thesis focused on the effects of computer game playing on spatial skills and examined the possibly differential response to training between the sexes. The concepts of computer games and spatial ability were introduced and previous studies in the subject area were also reviewed. The empirical research contained a five-hour 3D action computer game treatment, which was found not to have a significant impact on the subjects' mental rotation skills. The females in the experimental group gained more from practice than the males, but as an identical trend was visible in the control group as well, a conclusion could not be drawn. Statistically significant initial gender differences in mental rotation were not witnessed, experienced gamers' mental rotation skills were not markedly stronger than the non-gamers' skills, and neither success in a word game, nor in the 3D action game were found to correlate with mental rotation skills.

KEYWORDS: computer games, gender, mental rotation, spatial ability

TABLE OF CONTENTS

1 INTRODUCTION

"Given the growing importance of computers and video games as modern tools, their effect on cognitive skills is of interest from both a theoretical and practical perspective" (Subrahmanyam & Greenfield 1994, 14).

Action video games are the least studied genre amongst recreational forms of computer use, which have been relatively ignored as a means of informal education (Subrahmanyam & Greenfield 1994, 13). These games touch people on a mass scale, usually during the formative years of childhood when cognitive development is taking place (Greenfield, deWinstanley, Kilpatrick and Kaye 1994). It should, however, be noted that the symbolic universe of video games includes primarily younger people, which in this context refers to everyone under 35, as the first generation of video gamers have not given up their hobby although they have matured (de Aguilera & Mendiz 2003, 2).

Spatial skills are one of the areas of cognitive skills that many computer games require and therefore must promote as players become more skilled (Greenfield 1984, 104). The spatial skills involved in video games appear to be similar to the mental processes required in various spatial tests (Gagnon 1985, 165; Lowery & Knirk 1982-1983), and numerous studies (for example, Dorval & Pepin 1986; McGee 1978b; Scali et al. 2000) have found that spatial performance can be improved by practice. Gender-based differences in spatial skills have also been systematically studied, the differences are consistent, and men generally outperform women on spatial tasks (Linn & Petersen 1985; Voyer, Voyer & Bryden 1995; Roberts & Bell 2000, 1027; Greenfield & Brannon & Lohr 1994, 96). Spatial skills are crucial to success in many courses and lucrative careers (Brownlow et al. 2003, 371) plus have been linked to academic mastery of several sciences (Trindade et al. 2002). Okagaki & Frensch (1994, 34) suggest that improvement of spatial skills could be important for females: this may be especially critical in the computer industry, where there is a conspicuous gender gap between the number of male and female employees (Natale 2002, 24).

The aim of this empirical study is to focus on the effects of computer game exposure on spatial ability, and to examine the possibly differential response to training by females in comparison to males. The key concepts are "computer games" and "spatial ability"; computer games are introduced in Chapter 2 and spatial ability with its related issues are discussed in Chapter 3. Earlier research concerning the effects computer gaming on spatial skills is reviewed in Chapter 4. Chapter 5 presents experiments, which aim to demonstrate, whether or not computer game playing improves the subjects' mental rotation skills.

The focus on spatial skills in the experiments is restricted to mental rotation, as it is an area of spatial ability where gender differences according to various scientific studies (see, for instance, Linn & Petersen 1985; Voyer, Voyer & Bryden 1995; Okagaki & Frensch 1994; Roberts & Bell 2000; Brownlow et al. 2003) commonly exist and better results are obtained when more focus is placed on specific tasks, such as mental rotation, rather than on complex or broad tasks, such as visualization (Sans de Acedo Lizarraga et al. 2003). Both, short and long-term effects of computer game playing are investigated.

To underline the starting point of this study: earlier studies suggest that

- spatial skills can be improved by practice
- and that there are consistent differences in spatial ability between the sexes

This thesis attempts to 1) find out whether there are initial gender differences in the test group, 2) evaluate if spatial skills can be improved by computer game playing and 3) assess if the sexes gain differently from gaming.

The findings of the experiments are compared with the results of other similar studies in the final chapter (Chapter 6). The interest of this thesis lies in the unintentional cognitive effect of the games, and the overall intention is to provide additional information in the subject area.

2 GAMES

The goal of this chapter is to identify key events in the history of computer games, to present time periods that can be considered as separate eras in the evolution of computer games, and to divide computer games into different categories, often referred to as game genres, based on information found in literature and the world-wide web. The impact of computer games on society, or, for example, the psychological effects of computer game playing are not discussed, although minor remarks to the abovementioned and, for example, to the economical significance of the computer/video game business are made. Another aspect that is not the main focus of this chapter and is largely ignored is the development of computer hardware, although discussion of general level does take place.

2.1 Computer Game Defined

"A game is a collection of interesting choices", Sid Meier (Cadwell 2003), the man behind such games as, for example, Civilization and Railroad Tycoon (Mindjack 2003), once said. Kramer (2002) summarizes that games are “objects which consist of components and rules and have certain criteria: rules, a goal, always changing course; chance; competition; common experience; equality; freedom; activity; diving into the world of the game; and no impact on reality”. The definition below (The New International Webster’s Dictionary & Thesaurus 1999) is somewhat similar: “Any contest undertaken for recreation or prizes, played according to rules, and depending on strength, skill, or luck to win“, and “a video game is a game played using an electronic device with a visual display” (Free Online English Dictionary, Thesaurus and Encyclopaedia 2004).

Kangas (1998) discusses the term “computer game”, the various different mental images it brings to mind, the influence of games, popularity and players. She states that these mental images are often linked with games as entertainment, part of leisure and having fun. Kangas refers to games as "amusement applications".

> About the term computer game: This term is in sharp competition with video games, console games, and arcade games. Video games and console games usually means games connected to a TV, whereas arcade games means games placed in public spaces (and individual cabinets). Computer games are occasionally taken to mean games played on a PC. (Juul 1999, 8)

The term "computer game" in this thesis is used the same manner Juul explicates above and whichever term, arcade/computer/console/video game, or simply "game", is utilized, the intention is to refer to the area as a whole.

2.2 History of Computer Games

> THE ORIGIN OF GAMES has been vaguely assigned to the inborn tendency of the mankind to amuse itself. Games have no geographical boundaries and game playing is found in all parts of the world whether it is in the underdeveloped areas of Africa or in a plush New York apartment penthouse. (Spencer 1968, 3)

The history of the computer game is, in parts, a history of technology (Juul 1999, 7). Reviewing the history of computer games is not necessarily always started from the classic Spacewar (1962), after which gradually moving towards the present - there are many separate historical views (Suominen 1999, 170).

The division to different periods below is loose and strict definitions with start and end years have been left out. The conscious choice to omit these details is due to the fact that a degree of contradiction exists in between some of the referenced sources: for instance, Suominen (1999, 176) declares that Pong was released in 1972, Juul (1999, 8) says that it was released in 1973 and Kangas (1998) claims that it was in fact released in 1974. Suominen is the one presenting accurate facts in this case – the detail is also backed up by Kent (2001, xii).

The past, as presented in this chapter, is primarily based on Kent's (2001), Suominen's (1999) and especially Kangas's (1998) writings on the subject area.

Additional sources, some of disputable scientific validity, have also been cited where the information has been consistent with the aforesaid. Kangas divides the history of computer games into five periods. The division presented below is based on Kangas's example, with the additions of "World before Commercial Computer Games" and "New Era" – the periods Kangas' does not discuss.

World before Commercial Computer Games

> You can't say that video games grew out of pinball, but you can assume that video games wouldn't have happened without it. It's like bicycles and automobiles. One industry leads to the other and they exist side by side. But you had to have bicycles to one day have motor cars.
>
> -Steven Baxter, former producer, The CNN Computer Connection (Kent 2001, 1)

Juul (1999, 7) clarifies that the first computer game is generally assumed to be Spacewar, developed in 1962 at MIT by Stephen Russell. Prior to that, however, there were events that impacted the evolution of computer games - even though the events were not necessarily directly linked as such. Already in 1889 – Fusajiro Yamauchi established the Marufuku Company to manufacture and distribute Hanafuda, Japanese playing cards. The company later (in 1951) changed its name to Nintendo (Jones 2000; Kent 2001, xi). An event that according Kent (2001), "paved the way for today's computer and video game industry" was David Gottlieb's Baffle Ball in 1931 - a game that "used no electricity and bore little resemblance to modern pinball games". A couple of years before Russell's creation (Spacewar) in 1958, physicist Willy Higinbotham of the Brookhaven National Laboratories in New York invented an interactive table tennis-like game that was displayed on an oscilloscope (Kent 2001, xi; Kudler 2003). Suominen (1999, 172) writes about strategy and scenario –games, the first instances of which existed already in the 1950s. These were games, which in military use simulated war scenarios, but were also popular amongst commercial companies that utilized them, for instance, to aid managers in decision making.

Historically, the oldest coin-operated amusement machines were known as novelty games (Kent 2001, 9).

> By the 1960s, novelty games had become quite sophisticated. Black lights were built into the cabinets to make objects glow against dark backgrounds. One game, Chicago Coin Speedway, had a projection screen for a background. Players steered a race car in front of the screen, dodging the projected images of other cars. If the player came too close to a projected image, the machine made a banging sound to simulate a crash and the player went back to the back of the pack.
>
> These were the direct ancestors of modern video games. (Kent 2001, 10)

Kent also notes that in 1966, a game called Periscope was released – it became such a hit that U.S. and European companies began importing it. Periscope was Japan's first amusement game export, and in the U.S. the price ($0.25) charged from players by the arcade owners eventually became the standard price for playing arcade games. Juul (1999, 7) says that computer games were originally developed on equipment designed for military and academic purposes.

First Generation – the early 1970's

The first coin-operated video game was Computer Space, which was released in the United States in 1971 (Suominen 1999, 176). It did not become overly popular due to complex instructions as Nolan Bushnell, the creator of the game (and the co-founder of Atari), says (Kent 2001, 34). Atari engineer Al Alcorn created the first commercially available video game, Pong in 1972 (Kent 2001, xii). Kangas sees Odyssey by Magnavox being one of the first video game devices; it was released in the same year as Pong (Kent 2001, xii), but was outrageously priced and poorly advertised (Kent 2001, 26). Odyssey, according to Suominen (1999, 176), had neither colour, nor sound, but it could, however, be utilized for playing "ice hockey". Gunfight was the first major video game hit by a company called Midway. It was released in 1975 and it was the first video game with a microprocessor (Kent 2001, 64). Most games available in the mid - 70’s were ball & paddle games or sports games.

Second Generation – the late 1970’s

Game consoles gained increased success in the turn of the decade. Atari Video Computer System was released and it later became Atari 2600. The first computer games followed the space game boom started by Space Invaders (1978) and Asteroids (1979), the latter of which becoming Atari’s all-time best-seller (Jones 2000). Games such as Pac-Man were noted also amongst women and it was largely due to the aforementioned Space Invaders and Pac-Man that video games were found in virtually everywhere in America: Kent (2001, 123) refers to the years 1979-1983 as “The Golden Age”. Namco released Pac-Man in 1980 and it is the most popular arcade game of all time (Kent 2001, xiii). In the end of the 70’s the diversity of computer games had reached a point where games became an independent segment in the culture industry - the way music and movies had been for a long time.

Third Generation – the early 1980’s

Primitive graphics and repetitive game themes did not interest players anymore. Commodore Vic-20 changed the market situation by bringing in more advanced graphics and better sound abilities for reasonable price. In addition there was competition between products, such as, Atari 800, Radio Shack TRS-80 plus Apple II, and computer game play started shifting from arcades toward the home environment (Myers 1990, 290). In 1982 Commodore launched the Commodore 64: it went on to become a turning point in the history of home electronics, propelling Commodore into practically unheard of financial success (Kent 2001, 252). Juul (1999, 9) says that it would have already been “perfectly possible to network home computers like the Commodore 64, only nobody did”. In Finland, C64, amongst other microcomputers, including Sinclair Spectrum 48 and MSX (plus Atari ST and Amiga later on in the 1980’s), created a foundation for a completely new kind of youth culture (Saarikoski 1999, 158). It was not sooner than in the early 80's when the big companies in the entertainment business became seriously interested in the computer game market. Modern game industry evolved and as Choi (2003) puts it: video games were first introduced in the 1970's, but it wasn't until the 1980's that they became very popular. Some of the hit games of the era were Donkey Kong, released in 1981 by Nintendo (Kent 2001, xiii), and Mario Bros. released in 1983, in fact Mario appeared in Donkey Kong and Donkey Jr. (1982) as the "Jumpman" (Classic Gaming 2004).

Fourth Generation – the mid 1980's

Technical limitations and the inabilities of software houses to create new ideas led the video game industry to a crash in 1984 (Myers 1990, 292), the symptoms of which had been visible already for a few years. On the other hand microcomputers had improved and provided more complex possibilities for use and this interested consumers. The classic games of the era include such games as the space flight simulator Elite by a company called Firebird released in 1985, and the helicopter simulator Gunship made by Microprose in 1987 – these games simulated three-dimensionality, utilized vector graphics and consumed the processing power of the 8-bit computers thoroughly (Saarikoski 1999, 162). Tetris, developed by Soviet mathematician Alex Pajitnov in 1985 on an Electronica 60 gained huge success (Kudler 2003; Kent 2001, 377).

One of the new phenomena in the game market in the late 1980s were license games. Often the title and the idea were borrowed from a TV show or a movie (for instance, Ghostbusters or James Bond - A View to a Kill).

Fifth Generation – from the late 1980's until the late 1990's

The trend to create games that repeat or simulate reality gained popularity and software houses aimed to design games for new segments, such as girls, businessmen and students. The list of significant phenomena in the nineties includes such things as the releases of 3D first-person shooter Doom and game console Playstation. 3D games were not popular before the 1990's, however, there were some 3D games available, for example, Dungeon Master (by FTL in 1988) was a prototype of 3D games (Saarikoski 1999, 162), Battlezone (made by Atari in 1980), a game Kuittinen (1997) describes as "the first video game to feature truly interactive 3D environment" and Tail Gunner by Cinematronics, made in 1981, which according to Kent (2001, 130) is generally acknowledged as the first true 3D game. Prior to the eventual release of Doom there was a game called Wolfenstein 3D:

> In 1993, Wolfenstein 3D by Id Software takes the computer game industry by storm. Even though it wasn't actually 3D by today's standards, it can be considered the game which gave rise to the entire genre of first-person shooters. (Spohn 2003)

Doom was released in the same year and it established the 3D first-person shooter genre, a popular style of gaming that would top the bestseller lists for years. Juul (1999, 9; see also Kent 2001, 460) writes that it also demonstrated the entertainment power of multiplayer games: "The multi player game becomes widely popular when Doom (ID Software 1993) allows for connecting several PCs, for being several people present in the same game world", in addition the Internet taking off outside academic circles in the beginning of the 1990's facilitated the evolution of network gaming. Outcry over video game violence led to the creation of video game rating system and subsequently even more violent games (Jones 2000). In 1994, Sony released Playstation in Japan, and a year later in the U.S. (Kent 2001, xv). In 1997, three-dimensional graphics accelerators began to standardise (Jones 2000).

New Era

Computer games have maintained a certain type of marginality albeit they have risen from the 'remote area' to become one of the most important areas in the entertainment business (Kangas 1998) and have overtaken Hollywood movies and music business in annual profit (Kasvi 1999; Laird & van Lent 2001). As stated earlier, many commercial movies are repackaged as games; Star Wars is an obvious example. It is not rare that nowadays the repackaging also takes place the other way around. Games transferred into movies are less common though, as Juul (2001) reminds, but examples include Resident Evil, Final Fantasy and Tomb Raider (Herman et al. 2004). The consoles that currently dominate the markets are Xbox (Microsoft), GameCube (Nintendo) and PlayStation 2 (Sony). The list of popular games includes The Sims-series and the sports games by Electronic Arts (Madden NFL, NBA Street Vol. 2, et cetera), Pokemon by Nintendo, Grand Theft Auto III and Max Payne by Rockstar Games. Racing games have been especially popular in Finland: in 2002 the top 5 most sold games contained Colin McRae Rally 3.0, Rally Trophy and World Rally Championship (Suominen 2003). Natale (2002, 25) says that games directed for women tend to focus on stereotypes: the best-selling game for females is titled Barbie Fashion Designer (Mattel). Games have also found their way into mobile phones (such as Nokia's N-Gage) and handheld devices. At present and in the future, computers double in speed every 2-3 years, faster networks plus virtual reality interfaces continue their development, use of lifelike 3D characters increases, artificial intelligence plays an important role in games, many games have movie-size budgets (Jones 2000) and as Kuittinen (1997) predicted, an increasing number of game systems have the Internet connection as an option.

2.3 Game Genres

A genre is a category which classifies what kind of content and game play a game is likely to contain (Free Online English Dictionary, Thesaurus and Encyclopedia 2004). There are nearly as many different classifications for game genres as there are people classifying them, and categorizing certain games can be difficult (Suominen 1999, 171). The most fundamental characteristics of computer games, those that properly define genre, lie in the pattern of interactivity between player and game (Myers 1990, 298). Various authors have presented their own perception of how different type of games should be categorized into separate genres.

> As should become clear, there are many types of computer games. In the classical action game you can almost never win, the game just gradually becomes harder, and the highest honour achievable is to enter the high score list. The most general thing to say of the evolution of the computer game is probably that it has become gradually more based on genres. Almost all of the early computer games introduced new gameplay elements; later games tend to be examples of specific genres, borrowing traits from earlier games. (Juul 1999, 8)

Aalto and Hekanaho-Koivuvaara (1997, 21; see also Jokelainen & Maunula 2000, 13) sorted computer games into five separate genres: Sports, Adventure, Simulation, Fighting and Strategy. The Yahoo - directory (Yahoo! Games Directory 2003) categorizes video games into seven different groups: Action, Adventure, Puzzle, Recreation and Sports, Role Playing, Simulation and Strategy. The NPD Group (a marketing company) offers a fine grained classification scheme for game type which, according to Pagulayan et al. (in press) is quite often referred to in the games industry: Action, Fighting, Racing, Shooters, Simulations, Strategy/RPG (role-playing game), Family entertainment (primary objective is to interact with others and/or to solve problems), Children's entertainment (same as family entertainment but geared to a younger audience), Edutainment (primarily training systems that incorporate some elements of fun into their training regimen), Sports and All other games. Kangas (1998) sees eight different game genres; she has researched books and magazines, and the genres she presents are utilized as a loose foundation for the following categorization (other sources are cited when used), although there is room for personal interpretation. Some genres may overlap plus many games also blend elements from various genres and could be categorised as hybrids.

1. Puzzles, which according to Kangas include games such as Pac-Man or Tetris (not to mention Minesweeper). The character usually moves from one level to the next collecting different items (that give him points) and avoiding dangers. Tetris is probably the best-known puzzle game (and also the most addictive). Card games can also be seen to be a part of this genre.

2. Sports games. Examples include such games as the 1980s favorites Summer Games and Winter Games or today's popular sports games by Electronic Arts, for instance, FIFA World Cup2004 (Dyck et al. 2003). These games can be divided into two subcategories: Team Sports (usually the human controls one key player and the computer controls the others) and Individual Sports, such as driving, flying, skiing or snowboarding (Laird & van Lent 2001, 21).

3. Shooting games, for example, the classic Space Invaders or the legendary Doom, that evolved from Wolfenstein 3D, are considered as shooting games in Kangas's division, but the abovementioned have also been seen as action games (Laird & van Lent 2001). Dyck (et al. 2003) list Medal of Honor and Half-Life as examples of the 1st –person shooter genre. In these games it is often necessary for the player to annihilate everything.

4. Action. Most computer games belong to this genre. In these games a human player usually controls the character (from either first person or third person perspective in a virtual environment) and tries, for example, to save the world from evil (Laird & van Lent 2001). Kangas says that there are also various games of this type that have their storyline taken from a Hollywood movie, for example, Batman, Robocop or Last Action Hero. Laird & van Lent's series of popular action game examples includes Doom, Quake, Descent, Half-Life, Unreal, and Tomb Raider.

5. Adventure games. This genre has games that are either text-based (for example, Zork or Adventure; see Laird & van Lent 2001, 20) or graphic (Grim Fandango, Monkey Island). Adventure games generally involve a lot of

problem solving with the aid of different objects that can be collected during gameplay. Laird and van Lent expound that adventure games move further from action games, de-emphasize armed combat and, in addition to puzzle solving also emphasize story and plot. At the time of this writing, adventure games are considered unpopular and have nearly become extinct.

6. Role-Playing games (RPGs). A major part including MUDs (Multi User Dimensions/Dungeons) are sword-and-sorcer –type of themes. The environment can be ancient, medieval or even futuristic and is often based on a map or a map -like scenery. The Ultima-series is one of the most popular games of this genre. There is also a version of Ultima that can be played in a network: Ultima Online - this game was created in 1997 by Richard Garriott, a pioneer in the world of RPGs (Spohn 2003). The player can define different types of qualities and characteristics for his character in various different types of imaginary environments. Everquest and Asheron's Call are other examples of multiplayer role-playing games that thousands of people can play and interact in the same world (Laird & van Lent 2001, 19). Classic Examples of RPGs include: Ultima, Final Fantasy, The Bard's Tale and more recent examples include games, such as, Baldur's Gate, Icewind Dale (Scharff & McGinnis 2003). Kuittinen (1999) writes about a game type called Roguelikegames (in this paper considered a subcategory of RPGs) and clarifies that a roguelike game is a computer role-playing game (CRPG) which is similar to Rogue, the first roguelike game, created by Michael Toy and Glenn Wichman in 1980. These type of games do generally not have graphics (or the graphics are very simple), they are turn-based (they wait until the player enters a new command), non-real time, (usually) single-player games (excluding games such as Myth and Crossfire). Roguelike games usually take place in a fantasy setting. The most popular roguelike games according to Kuittinen are, for example, Zangband, Nethack and Ancient Domains of Mystery (ADOM).

7. Simulations, for instance, RealGolf, the SIM –series (which can also be seen as a God game) and Comanche 4 (Dyck et al. 2003) can be considered as simulations. The most common simulator games are flight simulators, sports simulators and space simulators. Simulations attempt to model real world and often the player is seated in the cockpit of a fighter plane. Pagulayan et al. (in press) put it eloquently: "the goal is to effectively control something that mimics behaviour in the real world".

8. Strategy games. According to Kangas, these games could be included in any other genre. This genre includes various board game-like applications such as Civilization or Populous. The player is often in charge of many units, such as military units and has to battle against one or more opponents (Laird & van Lent 2001, 21). Laird and van Lent also defined four separated categories of battle related with this genre: historical, alternative reality, fictional future and mythical. Often the player is in a position where he can attempt to rule the world or 'play God' and Laird & van Lent have in fact separated God Games into a category of its own. Examples: SimCity, which gives you the opportunity to orchestrate the building and development of a city (Friedman 1999), The Sims, and Railroad Tycoon (Squire 2000).

2.4 Games and Skills

There has been a lot of speculation regarding videogame playing and the development of various cognitive skills (Subrahmanyam & Greenfield 1994, 14; Gagnon 1985, 263). What skills are required by the games and what skills, therefore, the players might be developing (Greenfield 1984, 87)?

Even though some research on electronic games was carried out already in the beginning of the 1970s, scientific research into video games is still relatively rare (de Aguilera & Mendiz 2003, 3-5). Greenfield (1984, 96) explains that sensory-motor skills can improve by gameplay (and also emphasizes the significance of eye-hand coordination in everyday life and in certain occupations) and reminds that these, according to Piaget's theory[1] are the foundation for later stages of cognitive development. "Many computer games require the ability to coordinate visual information coming from multiple perspectives", and "this is a skill emphasized in Piaget's account of intellectual development" (Greenfield 1984, 104). It has been widely proposed that games teach various cognitive skills, increase attention spans and concentration plus spatial visualization (Gagnon 1985, 263). Furthermore videogames are claimed to teach decision making, following orders, and numerical and word recognition skills (Ball 1978; cited by Gagnon 1985, 264). In addition to the aforesaid, de Aguilera & Mendiz (2003, 11) state that stimulating motivation, acquiring practical skills, problem-solving, strategy assessment plus media and tools organization can benefit from videogame playing. Natale (2002, 24) speculates that computer games "may not be we once thought they were" – they may actually contribute to proliferated computer literacy. Greenfield (1984, 90) characterizes video games as "the first medium to combine visual dynamism with an active participatory role for the child" and is convinced that people who criticize video games do not understand what games involve (Greenfield 1984, 97). Polemic regarding the effects of regular computer game playing has often been based on opinions and speculations rather than on empirical findings (Dorval & Pepin 1986, 159) and Aguilera & Mendiz (2003, 1-2) point out that computer games are disparaged in terms similar to the ones utilized in criticizing television: some educational leaders reject games outright - blaming them for the growth of the culture of violence. Aguilera and Mendiz continue stating that a majority of officials and opinion leaders have never played video games; these attitudes are undoubtedly a product of "moral panic" – typical for out time. Miller and Kapel (1985, 160) explicate that simulation, or problem solving software have often been given a minor role in computer literacy; they theorize the game-like

[1] See Piaget (1952) for more information.

appearance, vague problem strategies, lack of direct relation to the content area and lack of measurement as being possible reasons for this. De Aguilera & Mendiz (2003, 11) emphasize that simulators as such, stand out for their enormous educational potential.

Disapproving views considering the benefits of computer gaming do also exist. According to Sims and Mayer (2002, 114) most video games are generally seen as recreational rather than educational tools. Squire (2002) asks, "What are people learning about academic subjects playing games such as SimCity, Civilization, Tropico, or SimEarth?" and ponders whether games may be used in formal learning environments, he suggests that playing games may not improve skills useful in other contexts:

> While pundits and theorists suggest that game-playing might be increasing kids critical thinking or problem-solving skills (See Katz, 2000; Prensky, 2000), research on transfer[2] gives very little reason to believe that players are developing skills that are useful in anything but very similar contexts. A skilled Half-Life player might develop skills that are useful in playing Unreal Tournament (a very similar game), but this does not mean that players necessarily develop generalizable "strategic thinking" or "planning" skills. Just because a player can plan an attack or develop a lightning quick reactions in Half-Life does not mean that she can plan her life effectively, or think quickly in other contexts, such as in a debate or in a courtroom - one of the main reasons being that these are two entirely different contexts and demand very different social practices.

Action video games were not designed to be educational tools, they were designed to entertain people; informal education is, however, education the effects of which are often described as unintentional (Greenfield, deWinstanley, Kilpatrick & Kaye 1994, 106).

[2] Transfer is the degree to which behavior will be repeated in a new situation (Detterman 1993, 4). See, for example, Mayer & Wittrock (1996) or Ellis (1965) for additional details.

Research has yet to prove that games are intellectually harmful - many studies defend the games' tremendous value in the development of intellectual abilities (De Aguilera & Mendiz 2003, 11).

2.5 Summary

This chapter listed meaningful events and phenomena in the evolution of computer games. Various game types were also introduced. Kangas's computer game genre categorization could be revised and expanded, for example, by such genres as Racing, Educational and Traditional games. Shooting could also be separated to subgenres (1st person shooters, 3rd person shooters and scrolling shooters); in addition to this it would seem appropriate to distinguish between Simulations and Simulators. The significance of games and the skills games require or improve were briefly discussed. It is evident that computer/video games have established a solid position as a form of entertainment and, apart from recreational purposes, the possible educational significance of computer games yet seems somewhat vague, however, appears to have potential and requires more attention.

3 SPATIAL ABILITY

As identified by Thurstone (1938), spatial ability is one of the primary mental abilities. This chapter focuses on the concept of spatial ability, the categorization of spatial skills and the related sex differences.

3.1 Definition of Spatial Ability

Studies infrequently define spatial ability (Voyer et al. 1995, 250). Halpern (1986, 48) states that the term "visual-spatial abilities" it is not an easy term to define because it is not a unitary concept, an issue on which researchers agree – it involves multiple processes and is a general label for describing several abilities (Linn & Petersen 1985, 1479; Voyer et al. 1995, 252). Richardson (1999, 35) says that the term is used to describe a very diverse collection of tasks which plausibly can only be carried out by some visual or spatial representation. Linn & Petersen (1985, 1479) write about activities as disparate as perception of horizontality, mental rotation of objects, and location of simple figures having all been referred to as measures of spatial ability. They unfold that "spatial ability generally refers to skill in representing, transforming, generating, and recalling symbolic, non-linguistic information" (Linn & Petersen 1985, 1482). "Spatial ability tests measure how individuals deal with material that is presented in space—in one, two or three dimensions—or how individuals orient themselves in space" (Contreras & Colom & Hernandez & Santacreu 2003). Spatial ability tests have also been regarded as measures of specialized mechanical aptitude or of 'concrete intelligence' (Macfarlane Smith 1964, 294). Specifically, spatial abilities "have to do with individuals' abilities in searching the visual field, apprehending the forms, shapes, and positions of objects as visually perceived, forming mental representations of those forms, shapes and positions, and manipulating such representation mentally" (Carroll, 1993, 304; cited by Contreras et al. 2003).

In summary, spatial ability generally is the ability to imagine what an irregular figure would look like if it were rotated in space or the ability to discern the relationship between shapes and objects (Halpern 1986, 48).

3.2 Categorization of Spatial Ability

No consensus exists for categorization of measures of spatial ability (Linn & Petersen 1985, 1479; Caplan et al. 1985, 786) and there is confusion (Caplan 1985, 789) plus little agreement between authors as to how spatial ability should be classified (Voyer et al. 1995, 251).

Linn and Petersen (1985) present a categorization, which separates spatial ability into three different types of spatial skills:

1. Spatial perception - the ability to determine spatial relationships with respect to the orientation of one's own body in spite of distracting information.

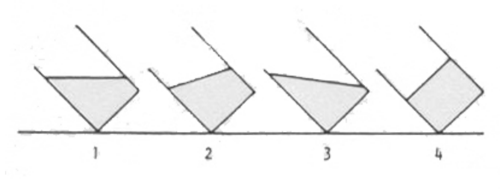

FIGURE 1. A spatial perception item. Respondents are asked to indicate which tilted bottle has a horizontal water line. (Linn and Petersen 1985, 1482)

2. Mental rotation - the ability to mentally rotate two or three dimensional figures quickly and accurately in imagination. In tests measuring mental rotation time is more critical than accuracy.

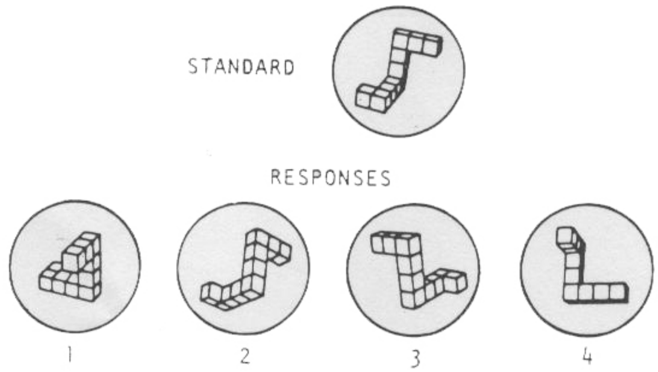

FIGURE 2. A mental rotation item. Respondents are asked to identify the two responses that show the standard in a different orientation. (Linn and Petersen 1985, 1483)

3. Spatial visualization is the ability to manipulate complex spatial information through several stages. It is commonly associated with complicated, spatial multi-step manipulations (such as mental paper folding). In spatial visualization tasks, mental rotation and spatial perception may, or may not be required in the solution strategy. Linn and Petersen (1985, 1485) summarize success of spatial visualization requiring “analysis of task demands and flexible adaptation of a repertoire of solution procedures”.

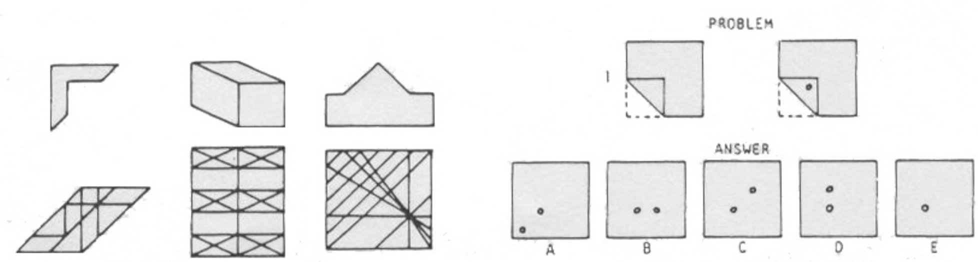

FIGURE 3. Spatial visualization items. Left, Embedded Figures: respondents are asked to find the simple shape shown on the top in the complex shape shown on the bottom. Right, Paper Folding: respondents are asked to indicate how the paper would look like when unfolded. (Linn and Petersen 1985, 1485)

The categorization above is at least “reasonably successful” (Voyer et al. 1995, 262). Other categorizations, however, are possible (Linn and Petersen 1985, 1485). Voyer et al. (1995, 252) criticize the categorization stating that the spatial visualization grouping appears to be a catchall category for what does not fit in the other categories. Caplan, MacPherson and Tobin (1985, 796) point the overlap out as well.

The following is a slightly different, alternative categorization of types of spatial skills identified by Guilford & Zimmerman (1948, 28; Lohman 1979; Subrahmanyam & Greenfield 1994, 14).

1. Spatial relations ability refers to the capacity to rapidly transform objects in mind. The Spatial Relations section in The Guilford-Zimmerman Aptitude Survey (Guilford & Zimmerman 1948, 28) was designed "to measure primarily an ability to appreciate spatial relations of things with reference to the human body".

2. Spatial visualization, the ability to deal with complex visual problems, for example, imagining relative movements of an image's internal parts or folding/unfolding of flat patterns. This factor, according to Guilford & Zimmerman (1948, 28) seems also to include transformations and can be considered dynamic (mechanical movements and mental paper folding are examples of dynamic spatial visualization).

3. Perceptual speed - this ability involves rapid encoding and comparison of visual forms. Visual objects need to be perceived quickly and accurately. Tests measuring perceptual speed do also often have strict time limits. Guilford & Zimmerman (1948, 28) state that in these tests "the examinee must note similarities and differences in the forms and details of common objects".

Guilford and Zimmerman (1948, 28-29) affirm that spatial relations and visualization have not always been separated: before the 2nd World War they were considered as one factor, "spatial". McGee (1979; cited by Halpern 1986, 49) separated "visual-spatial abilities" in only two factors: (1), a visualization factor, includes the ability to imagine how objects will appear when they are rotated or how a flat object will appear if it is folded or how a solid object will appear if it is unfolded and (2) an orientation factor, which includes the ability to detect relationships between different stimuli and the ability to perceive spatial patterns accurately. Gagnon (1985, 264) on the other hand, refers to four separate spatial skills in her study: spatial visualization, spatial orientation, spatial scanning and perceptual speed.

As illustrated above, different spatial factors have been isolated by various scientists, often meaning the same using different terms, or combining several factors to groups. The categorization by Linn and Petersen (1985), in spite of its limitations and the requirement for further refinement, has been accepted by various authors (see for example, Okagaki & Frensch 1994; Voyer et al. 1995; Richardson 1999; Scali et al. 2000).

3.3 Sex Differences

Sex differences in spatial ability are widely acknowledged (Linn & Petersen 1985, 1479) and robust. Differences in spatial performance between men and women are among the most consistent differences in cognitive abilities (Lawton & Morrin 1999). In other cognitive abilities, the sexes generally are closer to equal, excluding verbal ability, which is a female-dominated area. Maccoby (1966, 25-28) draws conclusions considering primary sex differences in intellectual functioning from studies by Anastasi (1958) and Terman & Tyler (1954):

1. General intelligence. Girls seem to succeed on tests of general intelligence during preschool years, boys in high school years.

2. Verbal ability. Girls tend to be superior to boys on tests of grammar, spelling and word fluency throughout all development stages.

3. Number ability. Girls learn to count earlier than boys. Boys start to forge ahead and excel in arithmetical reasoning in high school. Differences among college students and adults are in favour of men.

4. Spatial ability. There are no differences between the sexes in very young children carrying out spatial tasks, but from the early school years onwards, boys start to do better and this difference continues.

5. Analytic ability. The results are contradictory.

6. Creativity. The evidence favours women, but is not consistent.

7. Achievement. Girls obtain better grades through the school years, but men achieve substantially more (scientific achievements, artistic productivity, books written) in adulthood.

A study by Feingold (1988) suggests that cognitive gender differences in all areas (excluding mathematics, the test results in which are still in favor of males) have declined significantly during the latter half of the 20th century. Halpern (1986, 49) points out that some test results considering spatial skills and gender have been contradictory. Also the magnitude of the gender difference and the specificity of the difference with respect to type of spatial skills have been questioned (Caplan, MacPherson & Tobin 1985). Results vary depending on the test utilized (Halpern 1986, 49) and the lack of consensus in defining the term spatial ability accounts for some portion of the variability in findings (Caplan, MacPherson & Tobin 1985, 787); a test may be misclassified as a measure of spatial abilities, when it in fact measures something else (Caplan, MacPherson & Tobin 1985, 788). Goldstein, Haldane and Mitchell (1990) claim that the mental rotation performance of males and females would in un-speeded conditions be equal. This is proven false by Resnick (1993, 72-76) who demonstrates that despite unlimited time, a considerable proportion of women have a great deal of difficulty with the task.

Gender differences in spatial ability are moderate for spatial perception, significant for mental rotation and small, or non-significant for spatial visualization (Linn & Petersen 1985, 1491). Sex differences in spatial perception can be detected at the age of 8 or older (Linn & Petersen 1985, 1487). In mental rotation, males are superior to females at any age where measurement can be carried out (Linn & Petersen 1985, 1489). In spatial visualization no consistent differences are detected at any point in the life span (Linn & Petersen 1985, 1490; Voyer, Voyer & Bryden 1995, 257). The conclusion that gender differences in spatial visualization are insignificant may have been premature and partly due to the related definitional problems (Voyer et al. 1995, 262). It is worth mentioning that when studies with mature subjects are carried out the subjects are often composed of undergraduate students, seldom older than 30 years (Voyer, Voyer & Bryden 1995, 258, 265) and spatial skills start to decline after the third decade (Feingold 1988, 102). Therefore a more precise approach should be executed in order to obtain and draw reliable generalizations considering gender differences and spatial skills throughout the life span.

3.4 Explanation for Sex Differences

Gender differences in spatial ability have been explicated in many ways. Several factors, both, *environmental* (or sociocultural) as well as *biological* (genetic or physiological) may contribute to these differences, including gender-based socialization, practice, experience and efficacy beliefs (Scali et al. 2000; Voyer et al. 2000). The common assumption that the differences have a biological foundation is criticised by Caplan, MacPherson & Tobin (1985, 788), who suggest that theories have been constructed to explain sex differences. The X-linked recessive gene hypothesis, a theory that suggests that spatial ability may be inherited and enhanced by a recessive gene in the X-chromosome has not been confirmed (Richardson 1994, 436) and, for example, Gittler and Vitouch (1994, 407) underline the importance of the environmental influence. “According to Geary’s (1985; cited by Nordvik and Amponsah 1998) hypothesis, the gender differences in spatial ability may have evolved in the same process that created the gender difference in physical fitness, i.e., the male role as hunter and fighter required both strong muscles and spatial ability." Environmental explanations have focused on the differential experiences between the sexes and childhood training or differences in attitudes (Feingold 1988, 102): males perform activities that aid the development of spatial skills, such as woodworking, sports, model building (Scali et al. 2000) and computer games (Greenfield, Brannon and Lohr 1994; Subrahmanyam & Greenfield 1994). Voyer et al. (2000) expound that one of the increasingly popular ways to interpret gender differences in cognitive abilities is to consider that they arise from an interaction of biological and experiential factors, which means that when considering spatial skills, boys might tend to self-select into activities because of their inborn predisposition for spatial abilities.

As demonstrated earlier, Feingold (1988) claimed that the gender differences in spatial and other cognitive abilities are decreasing and that males are more variable in intellectual abilities. Voyer et al. (1995) and Richardson (1994, 445) found partial support for this, but Nordvik & Amponsah (1998) found no evidence that supports Feingold's claim. Nordvik and Amponsah (1998) rationalized that if gender differences in spatial skills are experientially determined and, for instance, due to societal changes, the difference should decrease as gender equality in roles, career options, et cetera, increases. The results in the studies by Nordvik and Amponsah (1998) were in favour of males and technology students, and in a mental rotations test male social sciences students scored higher than female technology students: male technology students scored highest and female social sciences students lowest on all the spatial ability tests. Nordvik and Amponsah (1998) state the effect of gender in their experiment having been greater than the effect of study group.

Some data, on the other hand indicate that women may differentially benefit from practice on spatial tasks (Voyer et al. 2000; Alington et al. 1992, 539). For instance, in an experiment by Roberts & Bell (2000), women improved at a greater pace than men on a computerized spatial task. Initial gender differences during the first session of the experiment did occur, but there was virtually no difference during the second session. On a paper-and-pencil test on the other hand, both sexes improved their performance, but men still succeeded better than women. Similar results have been obtained in studies focusing on the impact of video game playing on spatial skills (see Chapter 4), for example, in a study by Gagnon (1985), females, and novices in this case, did benefit more from practice than males - and in a study by Dorval & Pepin (1986), the sexes gained equally. The role of training in the attenuation of sex differences in mental rotation is yet unclear (Brownlow et al. 2003, 372; Roberts & Bell 2000).

Hormonal explanations have suggested that the amount of male testosterone correlates positively with spatial skills. Exploring the influence of hormonal variation is beyond the scope of this thesis, yet a reference can be made to Hooven et al. (2003, 782, 788). They conclude that, according to their findings, the efficacy of the mental rotation process is correlated with testosterone, which appears to facilitate processes related to other aspects of the task, such as encoding stimuli, initiating the transformation processes, making a comparison and decision, or producing a response.

Other factors may also cause variation in spatial performance in general. McGee (1978a, 83) clarifies the selection of a problem solving strategy affecting mental rotation test scores: individuals who prefer a visualisation strategy outperform individuals with a preference to orientation strategy. “Visualisation” refers to mentally rotating stimulus object in mind and “orientation” involves moving one’s body in relation to the stimulus object. It may be that men and women use different strategies (Lehmann 2000, 16).

3.5 Importance of Spatial Skills

Does having excellent spatial skills provide an advantage of some sort? It is generally agreed that spatial ability is an important component of intellectual ability, yet its nature needs to be made clear (Linn & Petersen 1985, 1479); spatial ability's usefulness as a construct is almost never questioned (Caplan, MacPherson & Tobin 1985, 786).

Success in scientific domains may be connected to spatial skills (Alington et al. 1992, 540). It also seems likely that high school subjects, such as mechanical drawing and analytical geometry, or other activities, as, for example, direction finding and map reading are involved in fostering spatial skills (McGee 1978b, 89). Studies have shown that spatial ability tests can aid to prognosticate success in certain areas, such as mathematics (Macfarlane Smith 1964, 295). Brownlow et al. (2003, 371) write that deficits in spatial abilities may contribute to women's avoidance of areas of study that rely heavily on spatial skills. Brownlow et al. (2003) present Chemistry (and also refer to math, and engineering) as an area, Trindade et al. (2002) mention Physics and Chemistry as areas, which require strong mental rotation skills, but conclude that women's lesser ability with mental rotation tasks seems not to be a significant contribution to women's avoidance to physical sciences.

In addition to science and the academic world, spatial skills are also required in certain professions in working life. Mental rotation ability is crucial to success in many courses and lucrative careers (Brownlow et al. 2003, 371). An example of these careers where spatial skills are needed is the air traffic controller (ATC), for which spatial ability is "especially germane for efficient performance" and spatial ability testing is important in the selection of applicants (Contreras et al. 2003); furthermore it seems likely that these skills are used extensively in engineering, architecture and building trades (Halpern 1986, 48). Guilford & Zimmerman (1948, 31) present a list of occupations, in which factors measured by their aptitude survey are probably important. This list, although 56 years old at the time of this writing and possibly slightly outdated, yet adds information and practicality to the subject, contains the spatial factors: perceptual speed, spatial orientation and spatial visualization. According to Guilford & Zimmerman's list (based on direct and indirect evidence plus enlightened guesses) spatial skills are beneficial to, for example, aircraft pilot, dentist, engineer, navigator and surgeon.

As mentioned above, spatial ability has been linked to academic mastery of several sciences (Trindade et al. 2002). When perceptual-spatial tests were given to 64 eminent scientists, they all showed superior scores in visual-spatial accuracy (Roe 1952, cited in Trindade et al. 2002). Lehmann (2000, 14) found that mental rotation performance strongly depends on the educational background: subjects attending a specific mathematical school, or students studying computer science outperformed all other subjects. Trindade et al. (2002) write that "visual-spatial learners may dislike traditional schooling because its overemphasis on lecturing, rote memorization, drill and practice exercises". As spatial skills are believed to be valuable, for example, in male-dominated fields such as engineering, computer science and mathematics, the importance of advancing these skills is obvious (Gagnon 1985, 274). It may also be that women, through training in rotation, could increase the liking of physical sciences (Brownlow et al. 2003, 379).

3.6 Summary

The magnitude and the nature of gender differences in spatial abilities, in spatial perception and especially in mental rotation, seems apparent, however, the cause of these differences yet remains to be determined. Gender differences have not been found in spatial visualization, which requires multi-step solution-procedures and the nature of which appears to be vague. Current explanations for existing gender differences cannot provide a clear answer and are mainly speculative; specific biological causes have not been established (Alington et al. 1992, 540). In addition to this, a plethora of non-identical definitions to spatial ability continues to exist (Caplan, MacPherson & Tobin 1985, 797).

Further research is also encouraged in defining the concrete gains and benefits that are achieved with strong spatial skills, or through training these cognitive abilities. For example, Trindade at al. (2002, 473) speculate that if "visual-spatial cognition is so fundamental in science, it should also be important in teaching science", which appears as an occurrence of the lack of comprehension related to the possible gains of spatial skills.

4 EFFECTS OF GAME PRACTICE ON SPATIAL SKILLS

Chapter Four presents and evaluates earlier studies concerning the effects of computer/video game playing on spatial skills. This literature review spans a time period of a quarter century and considers studies between 1978 and 2003.

4.1 Review

As early as in 1978, Ball analyzed the potential of video games for improving the spatial skills of children, with special emphasis on 3D features and real world simulation. In addition to this he researched the role of video games in the intellectual development of children and adolescents in learning language and mathematics. Ball concluded that video games are beneficial in learning assorted intellectual skills and various authors followed his footsteps. (de Aguilera & Mendiz 2003, 5)

In the beginning of the 1980's, Lowery & Knirk (1982-1983; cited by Gagnon 1985; Greenfield, Brannon and Lohr 1994, 89), similarly to Ball, reasoned that video games produced by the industry are suitable for enhancing spatial skills as spatial skills are built over a period of time and repeated interactions (cited by Subrahmanyam & Greenfield 1994, 15; see also Gagnon 1985, 265). They proposed that the fast-paced nature of videogames forces players to utilize spatial skills (cited by Gagnon 1985, 265) and suggested that in addition to spatial skills video game playing may also improve eye-hand coordination (cited by Subrahmanyam & Greenfield 1994, 14). For example, Space Invaders is described by Lowery and Knirk (cited by Gagnon 1985, 265) as a game, which requires "the ability to simultaneously coordinate horizontal and vertical axes and anticipate the intersection of imaginary lines".

Chatters (1984; a thesis, cited by Subrahmanyam & Greenfield 1994) tested sixth-grade children and found a remarkable positive effect on the WISC (Wechsler Intelligence Scale for Children) Block Design subtest after 3 hours 45 minutes of practice on Space Invaders. Chatters did not observe gender differences.

Gagnon's (1985) study was also one of the first experimental studies utilizing video game training (Subrahmanyam & Greenfield 1994, 15). Gagnon examined the relationship between video game playing, spatial skills and eye-hand coordination. Scores of two games, a two-dimensional game Targ and a three-dimensional game Battlezone (FIGURE 4), were compared with scores of three spatial skills tests (Spatial Orientation Test and Spatial Visualization Test by Guilford-Zimmerman, plus Psychological Services' Employee Aptitude Survey: Visual Pursuit Test).

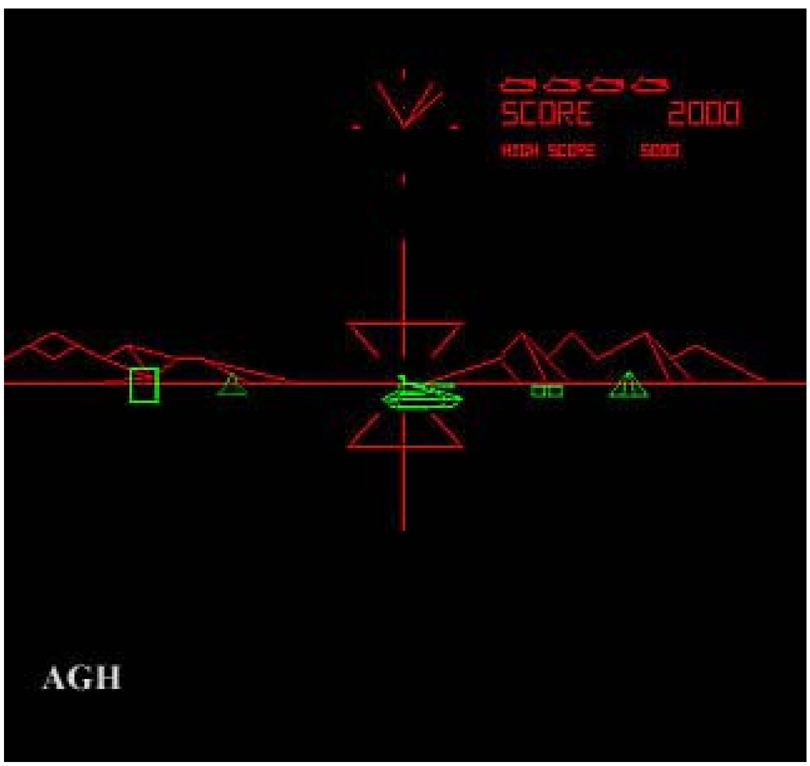

FIGURE 4: Battlezone, Atari Inc., 1980. "Battlezone was the first video game to feature truly interactive 3D environment. It had 2-color vector display. The United States Armed Forces were so impressed by the game that they commissioned Atari to build specially modified and upgraded versions for use in tank training." (Kuittinen 1997)

Small & Small (1982; cited by Gagnon 1985, 165) had pictured Battlezone a game which involves "elaborate spatial skills such as the ability to visualize rotation in three-dimensional space” - this detail presumably affected the game selection for the experiments. The subjects were undergraduate and graduate students who played the games for a total of 5 hours (2.5 hours each). Sex differences were found as follows: males scored higher on spatial orientation, visualization and the baseline measures on the game, Targ; females outperformed males on eye-hand coordination. Age correlated negatively on both, the spatial skills test scores and the videogames’ scores. The amount of past videogame experience correlated positively with the subjects’ scores on spatial tests. In addition to Gagnon, also Nordvik and Amponsah (1998), point out that according to their questionnaire, “Computer games” (along with activities such as “Knitting” and “Jig-saw puzzle”) correlate positively with spatial skills. Gagnon later discovered that the scores on two videogames correlated with different spatial test scores. Practice on videogames did not yield significant overall differences between the experimental and the control group, but it is noteworthy that the novices and especially the females in the experimental condition improved remarkably more on Spatial Visualization than the females in the control group. Women were also able to equalize their scores on “Targ” and Spatial Visualization with males when provided with videogame training.

Miller and Kapel (1985) carried out an experiment, which had a positive effect on subjects’ (7th and 8th graders) spatial skills (students were tested using Wheatley Spatial Test). A set of puzzle-type computer games were played by the experimental group. Puzzle-games were chosen as they do not require large amounts of specific knowledge and also due to the high interest-level. The games included ROBOT BLAST, a version of ‘Nim’; 3-D MAZE; PHAROAH’S NEEDLE, a version of ‘Tower’s of Hanoi’; HAMLET, a version of ‘Othello’; and FACTORY. Furthermore, other than spatial abilities, logical and sequential thinking were tested - there was a negative or no effect on those. The authors’ suggest that the result can possibly be explained by the fact that a greater portion of the class time in the computer lab was spent on FACTORY, the visual rotation element of which was most difficult for all subjects. The results were also evaluated through anecdotal information; the high ability group mastered problem solving strategies at a greater rate and the teachers reported that the high ability students were able to transfer strategies to content areas, albeit the high ability students had often difficulties in the beginning of the experiment and became easily frustrated.

In 1986, Dorval and Pepin tested whether playing Zaxxon (FIGURES 5 and 6) would enhance subjects' spatial visualization test scores (Forms A and B of the Space Relations Test of the Canadian Differential Aptitude Test, DAT, were used as measures of spatial visualization). The game, Zaxxon, was selected as it presents face validity for spatial visualization and it is well known to possess excellent qualities in terms of design and manipulation. Their first hypothesis that the test scores can be improved was supported by the results. Their second hypothesis was that women can improve more than men. Dorval and Pepin tested 70 undergraduate students, found no initial sex differences and their second hypothesis was not supported by the results as they concluded that males and females gained equally and significantly from playing Zaxxon. The subjects participated in eight sessions of five plays and the time interval between sessions was 1-2 weeks.

FIGURES 5 & 6 (The Video Game Museum 2004): Zaxxon by Sega/Gremlin 1982.

120 American fourth- and fifth-grade students, who had prior experience with computers participated in a study by Forsyth and Lancy (1987). The researchers

wished to establish whether playing an adventure game called "Winnie the Pooh in the Hundred Acre Wood" could teach place location information to students and whether they would enjoy the experience, which they did. The game was chosen as it is a simple, generic search-type adventure game and "simulates a simple, purposive exploration of a finite space" (Forsyth & Lancy 1987, 383). Place location is a part of the 'cognitive mapping' or spatial representation process which is universal among humans and present throughout virtually the entire life-span (Forsyth & Lancy 1987, 378). They assumed that using the computer as a means would be less successful with females – the assumption was suggested by available evidence. This assumption was proven false. Students learned to correctly identify places encountered in the game, subjects playing with a map were more successful, and there were no significant gender differences, which is what the researchers consider as "perhaps their most positive finding" (Forsyth & Lancy 1987, 389). In addition the authors underline that their study is one of the few studies, which involves games, to report no gender differences.

Children's, whom were fifth, seventh and ninth graders, mental rotation skills were improved by playing two games, The Factory, and Stellar 7 in a study by McClurg and Chaille (1987; cited by Greenfield, Brannon and Lohr 1994, 88). The skills improved – the study consisted of 12 sessions (cited by Sims & Mayer 2002, 99), 45 minutes twice a week for 6 weeks and the games require mental rotation and spatial visualization skills (cited in Okagaki and Frensch 1994, 36; see also Greenfield, Brannon and Lohr 1994, 89). Mental rotation skills were tested using a paper-and-pencil test featuring three-dimensional shapes. Boys' initial skills were better and the sexes benefited equally – whether the difference in skill-level remained throughout the experiment is unclear (see Subrahmanyam & Greenfield 1994, 16).

Subrahmanyam and Greenfield (1994) showed that playing a spatially oriented game, Marble Madness, improved children's spatial ability test scores more than playing a non-spatial computer game, Conjecture. Their sample included 61 subjects (28 boys, 33 girls) and the spatial skills were measured using a computer-based test battery by Pellegrino et al. (1987). Subrahmanyam and Greenfield (1994, 19) describe that Marble Madness was selected because it involves the use of “the spatial skills of guiding objects, judging speeds and distances of moving objects, and intercepting objects”. Conjecture is a non-spatial word game, similar to the TV show “Wheel of Fortune”. Spatial performance during pretest assessment was significantly better in boys than girls. The subjects in the experimental groups played either game for a total of 2 hours and 15 minutes, divided into three 45-minute sessions. Video game practice on Marble Madness was more effective on children who had poor initial spatial skills. Playing Conjecture did not improve performance. The authors suggest that video games may be utilized in equalizing individual and gender-associated differences in spatial performance. Subrahmanyam and Greenfield (1994, 26) also state that “the results confirm the thesis that video games are cultural artifacts that provide informal education for spatial skills”.

In a study by Greenfield, Brannon and Lohr (1994), the authors tested whether playing a three-dimensional action arcade game, Empire Strikes Back had an effect on the spatial skill of mental paper folding (the test itself was constructed by Brannon and Lohr). This study is unique in using the ecology of a video game arcade - experiments by other researchers have taken place in a laboratory or classroom setting. The subjects were undergraduate students and two experiments were carried out. The first experiment established a correlation between the game and the test. In the second experiment it was concluded that short-term practice on Empire Strikes Back did have no effect on mental paper folding, but long-term practice did. Greenfield, Brannon and Lohr figured out that gender does not influence the spatial skill in question directly, but through its influence on video game expertise.

Okagaki and Frensch (1994) carried out a study the conclusion of which supports earlier findings by Subrahmanyam & Greenfield (1994; Okagaki & Frensch 1994, 53; see also Sims & Mayer 2002, 100). Okagaki and Frensch found a difference in between the sexes when it came to playing Tetris and testing spatial ability; larger pretest-to-posttest gains were shown on male undergraduates (on 2 out of 4 tests taken from the kit by French, Ekstrom and Price 1963), but none on females. The subjects were older adolescents who had no prior experience in Tetris, which they played for 6 hours. Okagaki and Frensch (1994, 33) consider their findings as reliable and consistent in relation to gender differences in complex mental rotation tasks. Like earlier research, they conclude to have obtained mixed results (Okagaki & Frensch 1994, 54). They suggest that if the development of spatial skills within the video game context is an example of situated cognition (Brown et al. 1989), those who wish to "capitalize on the motivational aspect of video games for spatial skills training will need to find or develop games that are similar to the actual contexts in which the spatial skills will eventually be used".

Sims and Mayer (2002) executed two experiments regarding Tetris and mental rotation. They used computerized mental rotation tests similar to Shepard/Metzler (1971) and paper-and-pencil tests (Card Rotations, Formboard and Paper Folding tests) by Ekstrom, French and Harman (1976) to measure spatial skills. In the first experiment they compared spatial skills of students who were skilled in playing Tetris with students who had never played Tetris. In the second experiment Sims and Mayer compared two groups of non-Tetris players: the experimental group received 12 hours of Tetris playing practice and the control group received none. They concluded that the results obtained in Experiment 1 support a domain-specific theory of problem-solving transfer in which spatial cognitive skills learned in one domain do not generally transfer to other domains. The results of their experiments show that Tetris expertise is related only to performance on spatial ability tasks involving mental rotation of

Tetris shapes, or shapes very similar to Tetris shapes. Furthermore, Sims and Mayer showed that skilled Tetris-players executed mental rotation procedures more quickly than other players, notwithstanding the procedures were the same. They found no evidence that 12 hours of Tetris-playing in the second experiment had any impact on the subjects' spatial skills.

Green & Bavelier (2003) carried out a set of five experiments, with subjects aged 18-23 years, exploring whether visual skills can be altered by video-game playing. Four of the experiments manage to establish changes in different aspects of visual attention in habitual video-gamers as compared with non-video-game players. Video-gamers, who had played action video games, such as Grand Theft Auto III (Figures 7 & 8), Half-Life, Counter-Strike, Crazy Taxi, Team Fortress Classic, 007, Spider-Man, Halo, Marvel vs Capcom, Roguespeare and Super Mario Cart on at least 4 days per week for a minimum of 1 hour per day for the previous 6 months, had significantly increased attentional and visual skills.

FIGURES 7 and 8 (The Video Game Museum 2004): Grand Theft Auto III.

In the fifth experiment a group of non-video-game players went through training, in which the participants played Medal of Honor: Allied Assault (Electronic Arts) for an hour per day for 10 consecutive days. The control group played Tetris. The subjects who had been playing Medal of Honor showed greater improvement in visual attention, spatial distribution and its temporal resolution than the control group. Green and Bavelier (2003, 536) provide an explanation according to which Tetris has a challenging visuo-motor component, but demands focus on one object, whereas action games require that attention is distributed and/or switched around the field. Green & Bavelier (2003, 536) conclude that "although video-game playing may seem to be rather mindless, it is capable of radically altering visual attentional processing".

4.2 Summary

Different types of games provide their own operational requirements and may in spite of similarities, require different cognitive and other skills. Computer games and the effects of which in studies are, however, often generalized. Gagnon (1985, 271) points out different videogames appearing to use or be related to different types of spatial cognitive skills; many of the studies discussed in this chapter fail to underline this issue: a limited number of computer/video games is utilized in experiments and a general conclusion is drawn. It should be noted that, for instance, a game, such as Tetris may require and improve skills very different from a 3D action game from either the 1st, or the 3rd person perspective. As clarified in Chapter 2.2, computer games have evolved rapidly, and the games in the 1980’s (Pac-Man, Donkey Kong, et cetera) were compact in comparison with the 1990’s 3D games (Tomb Raider, Doom, etc). Three-dimensionality up to today’s standards is a component that can be found scarcely in the games that studies discussed in this chapter examine; merely in research by Greenfield, Brannon & Lohr (1994) and Green & Bavelier (2003).

This chapter introduced manifold studies focusing on the effects of computer gaming on spatial abilities. The researched spatial factors, the subjects used in the experiments, the games played, and most importantly the primary conclusions were presented. All studies reviewed reported improved spatial performance (of varying levels) through gaming. It may be that exposing individuals to an activity they are not familiar with and "forcing" them to utilize mental processes that have deteriorated, or that have never been practiced, manages to stimulate spatial skills. Unlike other studies, Sims & Mayer (2002) and Greenfield, Brannon & Lohr (1994) did not discover short-term practice having any effect on spatial skills – only long-term practice was successful; this seems logical and is also an interesting finding as a 12-hour practice in Sims & Mayer's study had no effect, when a 6-hour practice on the same game (Tetris) in an experiment by Okagaki and Frensch (1994) led to different result.

Some gender differences were observed in the studies discussed. Gagnon's (1985) experiments' lacked overall effects (anyhow a positive correlation between the amount of past videogame experience and spatial test scores were shown), but the females improved significantly on spatial visualization. McClurg & Chaille (1987) and Subrahmanyam & Greenfield (1994) mention males outperforming females on the initial spatial test scores. Okagaki and Frensch (1994) witnessed larger pre- to posttest gains on males than females, and Dorval & Pepin (1986), Forsyth & Lancy (1987) and McClurg & Chaille (1987) state both sexes gaining equally from game-practice. Studies with larger samples and a greater number of games, or a meta-analysis are required in order to draw a further conclusion.

5 EMPIRICAL EVALUATION

This section contains an empirical evaluation of the impact of computer game playing on mental rotation (MR) skills. The attention was focused on mental rotation as it is an area of spatial ability where consistent gender differences exist. Three experiments were carried out in order to search answers for the central research questions.

5.1 Hypotheses

The main research questions were the following:

1. Are there initial gender differences in the test group?

The first hypothesis is that males will perform better in the initial pre-test, due to males' cognitive superiority in mental rotation. A null hypothesis is that there are no gender differences on average.

2. Can spatial skills be improved by computer game playing?

The second hypothesis is that exposing the subjects to playing a game, where they are required to act in a virtual environment and forced to react fast, improves their Mental Rotation Test performance. Therefore, the experimental group is expected to make greater pretest-posttest advancement than the control group (playing the non-spatial game is expected not to improve the subjects' mental rotation test scores). Furthermore, the experienced players in group 3 are expected to be superior to the novices. The null hypothesis is that there are no differences between groups 1 and 2 in the post-test, or between the experienced gamers and the other subjects in the pre-test. It is also assumed that there is a relationship between spatial expertise and success in computer game play: in Group 1, individuals with strong mental rotation skills are expected to progress further in the game than individuals with weak skills.

3. Do the sexes gain differently from gaming?

The third hypothesis is that females are expected to make greater pretest-posttest improvement as their mental rotation skills are assumed to be further from their potential maximum: this would leave more room for improvement (see, for example: Voyer et al. 2000; Alington et al. 1992, 541). The null hypothesis: significant differences in improvement between the sexes are not found.

5.2 Design

The research design consisted of three separate groups of subjects, a mental rotation test, two computer games, and questionnaires the subjects were required to fill in.

Subjects

A total of 20 subjects participated in the experiments, 2 of whom were excluded from all statistical analyses as they failed to reach an acceptable level of accuracy (>=90%) in the Mental Rotation Test (their scores were interpreted as scores of an individual under the influence of alcohol or suffering from mental disorder). Each of the three groups therefore consisted of 6 subjects (3 x 6 = 18 subjects total). The subjects were recruited primarily with the aid of the mass-mailing lists of the University of Jyväskylä using free cinema tickets as an incentive to participate: two tickets were given to each individual in Group 1, while the participants in the other groups were rewarded with a ticket per person. The subjects consisted of graduate and postgraduate university students from various faculties and universities both local and international.

The subjects in *group 1* (3 males aged 26.7 on average, 3 females aged 22.7 on average) were individuals who had very little, or no previous experience in computer game playing. The subjects in *group 1* (the experimental group) played a commercially available, popular computer game that simulates three-dimensionality. The game was played for 5 hours during one week, in accordance with a study by Gagnon (1985). As a result of schedule problems and absenteeism due to health-related issues, adjustments were made in the way that the subjects were allowed to divide the five-hour period to match their personal timetables (some subjects played 5 x 1h, some played 2h+2h+1h, or 1h+1h+1h+0h+2h). The subjects were allowed to ask for instructions during the game-playing sessions. The subjects' mental rotation skills were tested pre and post game-playing.

Group 2 played a word-game, which was not expected to require or stimulate spatial skills. The approximate time period between pre-test and post-test was one hour. The design of experiments 1 and 2 was identical except for the actual game and the time frame utilized. In Group 2 the average age of the males was 25.3 years and the females 24.0 years.

The subjects (6 males) in *Group 3* were experienced video-game players (VGPs; Green & Bavelier 2003, 534). VGPs, who as in an experiment by Green & Bavelier (2003), were recruited under the condition that they have played computer games actively for the previous 6 months at least 4 days per week for a minimum of 1 hour per day. The subjects were aged between 21 and 24 years and had an average of 13.6 years gaming experience - the frequency of which varied from 2 to 7 days a week. One of the subjects stated that he had 14 years of game experience, but nowadays he only plays now and again. The list of games the subjects reported playing included, for example, such games as Half-Life, Counter-Strike, Duke Nukem, Metal, Gear Solid 2, Return to Castle Wolfenstein: Enemy Territory, Operation Flashpoint, Tie Fighter, Final Fantasy 7, Morrowind, Command & Conquer, Grand Theft Auto 3, Unreal Tournament, Warcraft 3, X-Wing, Dune 2, Doom I & II, Red Alert, Monkey Island 1 & 2, Hitman 2 and Splinter Cell. The subjects in Group 3 were required to take the Mental Rotation Test only once.

Test

A computerised Mental Rotation Test (MRT; see Appendix A for screenshots and Appendix B for a raw data example) was constructed according to instructions supplied by Professor Pertti Saariluoma (University of Jyväskylä) specifically for this study. The test includes 185 mental rotation items (15^{o} intervals) consisting of the letter 'R' and its mirror image (which account for a total of 48 variations). The first 5 items in the test are considered as practice and not included in the final score. The subjects were required to obtain a score with an accuracy of >= 90% in order to qualify. The Mental Rotation Test scores were used as primary data and the scores were calculated by the formula: total time * (total number of questions/number of correct answers). For example, if a subject's time spent on correct answers had been 150 seconds and he had scored 170 out of 180, his final score would have been 150 * (180/170) = <u>158.8</u> seconds; a smaller number indicating a faster response time and hence a better score.

Games

Group 1 played a popular 3D action game Grand Theft Auto: Vice City (Rockstar Games). GTA Vice City is a cinematic action extravaganza from the 3rd person perspective. The player can move freely in a virtual city and the basic idea is to advance in criminal hierarchy. The game was chosen as it is a prime example of a celebrated, modern computer game – its predecessor GTA III was elected Game of the Year 2002 in a Finnish computer magazine MikroBitti (Alanen 2003, 99). In addition GTA is versatile and making progress in the game does not depend solely on lightning-fast reflexes (as in myriad 1st person shooters), the difficulty-level increases gradually, and due to GTA's addictive nature it stood out as a game that would remain fascinating throughout the test period.

Group 2 played a game called CrossCraze (ORT Software), which is a scrabble-like, classic vocabulary game. The subjects played against the artificial intelligence of the computer.

The games were installed on PC computers with Microsoft Windows XP as the operating system. Standard keyboards and mice were used as control devices.

Questionnaires

The subjects were inquired to fill in their personal details including name, age, gender, faculty, major subject and nationality. Participants in groups 1 and 2 were also encouraged to fill in details considering their game performance (the purpose of this somewhat trivial activity was to track their progress and to motivate them by creating an illusion of the vitality of the scores). Individuals in Group 3 were asked about their past computer/video game experience and the games they had played intensively. See Appendix F for the questionnaires.

5.3 Results

Data were analyzed using SPSS 12.0.1 for Windows. Group and Gender were used as the main independent variables. Mental Rotation Test scores (the time, the faster the better) were used as the primary dependent variables. The level of probability utilized was .05.

1. Were there initial gender differences in the test group?

Statistically significant gender differences were not observed amongst the participants in Groups 1 and 2. Males' initial Mental Rotation skills were 'more desirable. The standard deviation and standard error statistics (TABLE 1) tell that males were in addition slightly less variable, but as TABLE 2 (Appendix C) shows the difference in favor of males is by no means statistically significant ($p > 0.05$), thus one fails to reject the null hypothesis. Often reported gender differences favoring males were not found

	Subject's gender	N	Mean	Std. Deviation	Std. Error Mean
Pre-test time on MRT	Male	6	257,52967	72,048118	29,413521
	Female	6	281,04567	111,846082	45,660972

TABLE 1. Gender differences in Groups 1 and 2 combined.

2. Can spatial skills be improved by computer game playing?

To test whether the experimental treatment improved the subjects' Mental Rotation Test performance a Two-way Analysis of Variance was executed with Group and Gender as the independent variables. The change scores (post-test score minus pre-test score) were used as the dependent variables: these were converted to relative improvement in percentages.

TABLE 3 shows (in addition see TABLES 4 and 5 in APPENDIX D) that none of the terms are statistically significant. A tendency is noted for "Gender" [F(1, 8) = 4.944, p < 0.10]. There were no reliable effects obtained with the analysis.

Tests of Between-Subjects Effects

Dependent Variable: Improvement %

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	966,529(a)	3	322,176	2,652	,120	,499
Intercept	4916,701	1	4916,701	40,473	,000	,835
Group	254,841	1	254,841	2,098	,186	,208
Gender	600,667	1	600,667	4,944	,057	,382
Group * Gender	111,021	1	111,021	,914	,367	,103
Error	971,860	8	121,483			
Total	6855,090	12				
Corrected Total	1938,389	11				

a R Squared = ,499 (Adjusted R Squared = ,311)

TABLE 3. ANOVA table shows insignificant results.

The subjects' Mental Rotation Test improvement in both, experimental and control condition is illustrated in FIGURE 9. Overall, the control group was slightly less skilled compared with the experimental group. As can be seen, the females were inferior to males in the initial Mental Rotation Test in both conditions, but outperformed males on the post-test. The experimental group gained more from game treatment than the control group, but this is statistically non-significant. It can be concluded that the treatment itself had no effect on the Mental Rotation Test performance. Plausible evidence to support the second hypothesis was not found.

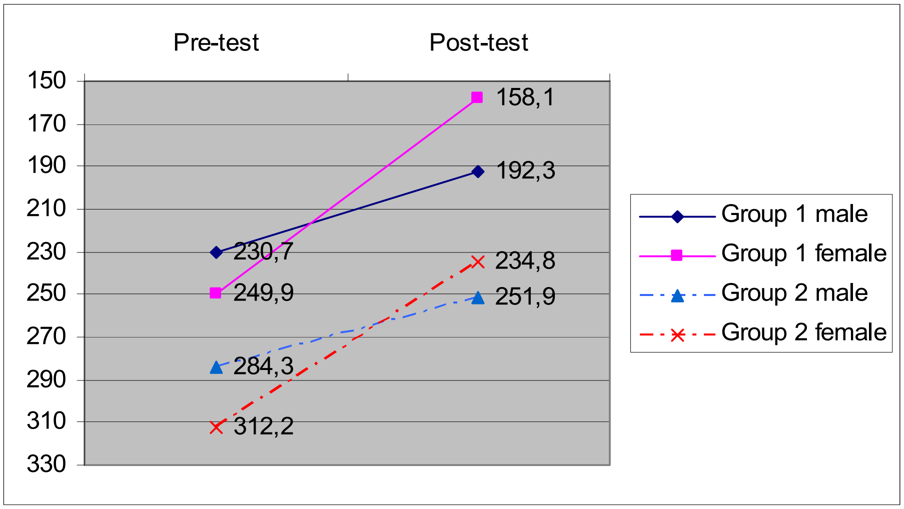

FIGURE 9. Pre- and post-test conditions displayed in a line graph. The time (in seconds) is shown on the left. The upper lines show the situation in Group 1 (experimental group) and the lower ones clarify that a nearly identical phenomenon was witnessed in Group 2 (control group): the females were inferior to males in the Mental Rotation pre-test, but superior in the post-test.

In order to examine whether the experienced video-game players (VGPs) of Group 3 differed from the non-video-game players (inexperienced males = NVGP males; inexperienced females = NVGP females) in the other groups, an Analysis of Variance (ANOVA) was carried out. Table 6 displays the descriptive figures for different groups, according to which the VGPs were the fastest, the NVGP males were next and the females were the slowest in the initial Mental Rotation Test. The One-way ANOVA led to insignificant statistical findings ($p > 0.05$; see TABLES 7, 8 and 9 in Appendix E). There is no convincing verification to believe that these groups differ: one fails to reject the null hypothesis.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
NVGP males	6	257,52967	72,048118	29,413521	181,91980	333,13953	150,000	360,000
NVGP females	6	281,04567	111,846082	45,660972	163,67040	398,42093	155,866	469,704
VGP males	6	220,86717	49,961246	20,396593	168,43605	273,29828	158,023	296,000
Total	18	253,14750	81,175266	19,133194	212,77999	293,51501	150,000	469,704

TABLE 6. The table shows the descriptive statistics for NVGP males, NVGP females and VGP males concerning the pre-test scores. The groups were compared in order to figure out if the experienced gamers were more skilled. Experienced players succeeded slightly better in the Mental Rotation Test, but this is not statistically significant and does indicate any reason to reject the null hypothesis.

In addition to the primary research questions, of particular interest were the possible correlations between mental rotation skills and success in the games played. A Pearson's Correlation Coefficient was performed (TABLE 10). Correlations between these variables were not found, which in the case of MR skills and success in the 3D game is contrary to what many studies report. Besides the correlations shown in TABLE 10 it was also witnessed that age did not correlate with mental rotation skills.

		Mental rotation	3D game	Word game
Mental rotation	Pearson Correlation	1	,401	-,089
	Sig. (2-tailed)		,431	,867
	N	18	6	6
3D game	Pearson Correlation	,401	1	.(a)
	Sig. (2-tailed)	,431		.
	N	6	6	0
Word game	Pearson Correlation	-,089	.(a)	1
	Sig. (2-tailed)	,867	.	
	N	6	0	6

a Cannot be computed because at least one of the variables is constant (subjects who played the 3D game did not play the word game)

TABLE 10. A Pearson's Correlation Coefficient was performed to explore if there were correlations between mental rotation skills and success in the games. The Mental rotation – variable is a mean between pre-test and post-test. The subjects' "Criminal ratings" in GTA after 5 hours of play were used as a measure of success in the 3D game. An average score was calculated for the word game. No significant correlations were found.

3. Did the sexes gain differently from gaming?

As shown earlier, women were inferior in pre-test, improved more than men and outperformed men in the post-test, but as the trend is nearly identical in both, the experimental and the control groups, it is evident that the result is not due to the actual computer game training. The statistical support for the hypothesis is insufficient.

5.4 Conclusions

These experiments showed no plausible substantiation to reject the null hypotheses. The first hypothesis was not supported by the findings as significant initial differences between the sexes were not observed, notwithstanding males were inconsiderably superior. Support for the second and the third hypotheses were not found: even though the experiments managed, not only to narrow the gender gap in mental rotation, but to nullify the difference, the phenomenon was visible in the control group as well and therefore was not due to the game treatment itself.

Other assumed correlations were not witnessed either. Experienced gamers' mental rotation abilities did not differ significantly from those of the other subjects – it should, however, be noted that one has no proof considering Group 3's MR skills prior to taking up computer/video games. Although it has been proposed that spatial skills decline through age (Feingold 1988, 102), age did not correlate with spatial skills - the outcome can possibly be explained by the fact that most subjects were approximately the same age (in their twenties). In addition, regardless of the fact that spatial reasoning has been presented as the main challenge to a vast majority of computer games (Natale 2002, 25), correlations between Mental Rotation Test results and success in the computer game were not found. Of relevance is the notion that, as one of the subjects in the experimental condition mentioned, "this game is multi-dimensional", meaning that the game (as various modern computer games), in addition to spatial skills requires a wide range of components, characteristics, skills and abilities, such as eye-hand coordination, decision making, persistence and creativity, which affect the overall progress in the game.

The results of the experiments do not necessarily indicate that the null hypotheses are true – the evidence against them is simply not convincing.

6 DISCUSSION

This thesis focused on the unintentional cognitive learning effects of computer/video game practice on spatial skills, discussed computer game genres and the evolution of games, introduced spatial ability, reviewed related studies and presented findings based on the empirical research that was carried out.

Issues that require additional research in order to be resolved were pointed out after the literary review in Chapter 3: 1) the causes of sex differences in spatial ability are to be determined and furthermore, 2) the gains that can be obtained by improving spatial skills should be defined thoroughly. For example, what are the areas in everyday life that could benefit through training spatial skills by computer game practice? The aforementioned are ideal and pertinent themes for further studies.

Despite the diversity and the lack of uniformity in the earlier studies reviewed in Chapter 4, the studies nevertheless manage to identify a connection between computer games and spatial ability and also establish prospects of games as a medium for informal education.

The empirical section, Chapter 5, yielded results that did not to lead to a substantial aftermath. Action video games in general, have been the centre of attention in discussions concerning the effects of video game violence (see Funk, Pasold & Baumgardner 2003), but have been scarcely studied for any kind of educational purpose. Of the research reviewed in Chapter 4, few of the studies contain action games: except the ones executed by Greenfield, Brannon & and Lohr (1994) and Green & Bavelier (2003). The experiments showed that playing the 3D action game had no beneficial effect on the skill of mental rotation. The women gained from game practice and were able not only to equalize their MRT scores with men's scores, but to actually outperform men -

yet the phenomenon was also present in the control group and therefore concluded not to be due to the game treatment itself. The effects were insignificant; argumentation regarding achieving significance through a larger sample size is, however, sheer speculation.

The participants were satisfied with the game selected for the main experiment. Intriguingly, the females in the experimental group seemed observably enthusiastic about the game, perhaps even more so than the male participants, which is an exciting notion as (albeit the subjects were recruited explicitly for a "computer game" experiment and therefore it is safe to assume that also the female participants regardless of their lack of previous game expertise had a positive attitude towards gaming) the game, Grand Theft Auto: Vice City, played by the experimental group includes a lot of realistic violence and, for example, Greenfield, Brannon & Lohr (1994, 99) surmised that the game's violence-content in their study was possibly a motivational turn-off for women. The experiments in this thesis indicate the opposite - yet on the other hand as Kangas (2000, 97) emphasizes: gender does not define a single homogenous target crowd. It is beyond the scope of this thesis to determine the underlying reasons for females' overall lack of interest towards games (Natale 2002). An opportunity for individuals to benefit from gaming is evident, as shown by studies in Chapter 4, and therefore an issue of interest.

The subjects were visibly puzzled in the beginning of the experiment and appeared to have problems, for instance, in comprehending and controlling the camera-angle in the 3D game. Hence game playing ability developed throughout the experiment amongst the participants. For future reference, excluding factors, such as, the effect of improved dexterity, or advanced reaction speed should be excluded: this could be achieved by extending the test battery – these details are essential and should be taken into account in further studies in order to be sure of the fact that it really is the skill of mental rotation that develops and not, for instance, visual alertness.

Conducting further research with larger sample sizes, a longer test period and a more versatile test battery is encouraged.

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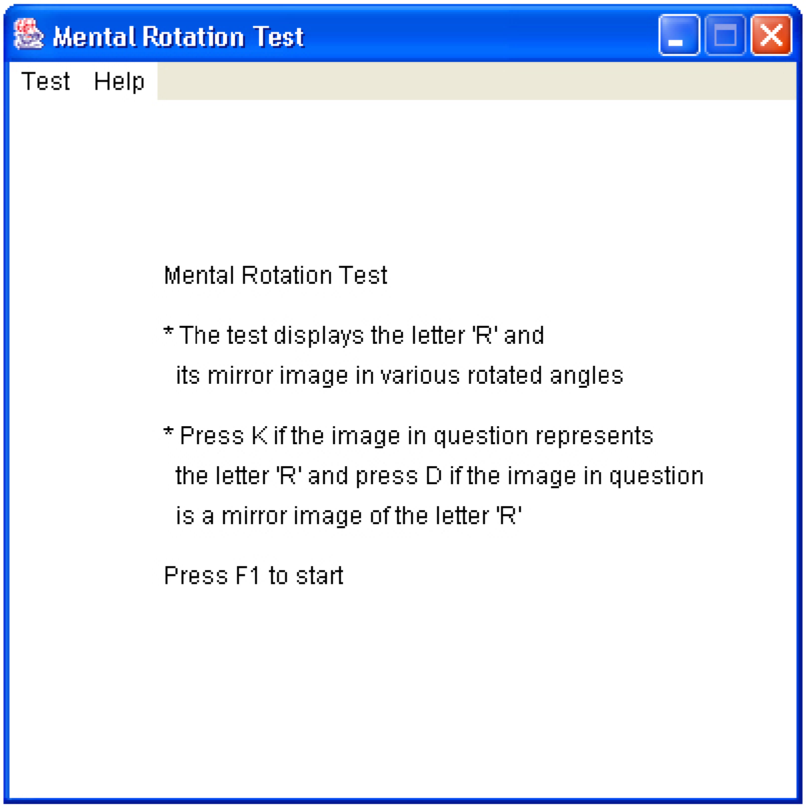
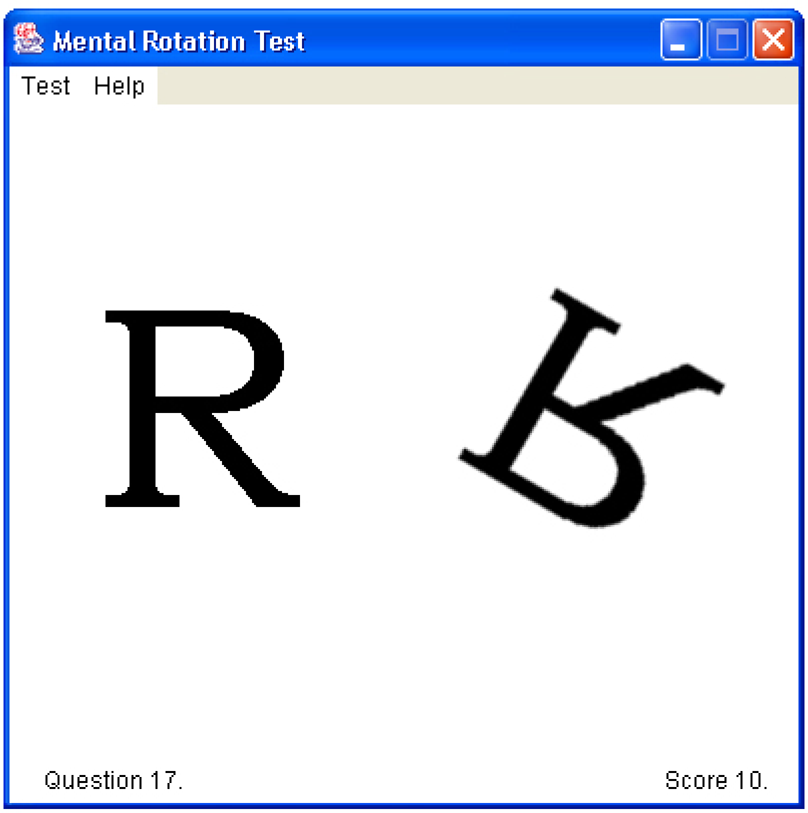

Mental Rotation Test
Test Help
Mental Rotation Test
* The test displays the letter 'R' and its mirror image in various rotated angles
* Press K if the image in question represents the letter 'R' and press D if the image in question is a mirror image of the letter 'R'
Press F1 to start


Mental Rotation Test
Test Help
R
Question 17.
Score 10.

Mental Rotation Test Results

Subject: ***
Date: Fri May 14 12:04:14 EEST 2004

I Question number
II Rotation angle
III 0/1 (0=normal orientation, 1=mirror image)
IV Subjects's answer
V Time spent on answer in milliseconds

1	45	0	0	702.0
2	90	1	1	2306.0
3	255	0	0	1465.0
4	135	0	0	1262.0
5	120	1	1	841.0
6	285	1	1	3647.0
7	360	0	0	966.0
8	165	0	0	1698.0
9	30	0	0	1138.0
10	150	1	1	950.0
11	165	1	1	702.0
12	75	0	0	701.0
13	315	1	1	639.0
14	135	1	1	857.0
15	60	1	1	608.0
16	300	0	0	592.0
17	60	0	0	1059.0
18	15	0	0	483.0
19	195	0	0	951.0
20	105	0	1	639.0
21	330	0	0	701.0
22	90	0	0	639.0
23	300	1	1	545.0
24	315	0	0	655.0
25	330	1	1	935.0
26	15	1	1	576.0
27	240	1	1	811.0
28	120	0	0	1682.0
29	285	0	0	1232.0
30	345	0	1	888.0
31	225	1	1	3163.0
32	75	1	1	561.0
33	0	1	1	530.0
34	150	0	1	685.0
35	240	0	0	1091.0
36	345	1	1	686.0
37	225	0	0	1527.0
38	210	0	0	686.0
39	45	1	1	888.0
40	255	1	1	1153.0
41	180	0	0	1091.0

42	30	1	1	623.0
43	210	1	1	1013.0
44	300	1	1	654.0
45	45	1	1	655.0
46	90	0	0	1433.0
47	165	0	0	1746.0
48	75	1	1	514.0
49	330	0	0	919.0
50	120	0	0	1387.0
51	180	1	1	873.0
52	30	1	1	716.0
53	210	1	1	1450.0
54	135	0	0	1153.0
55	315	0	0	670.0
56	150	1	1	810.0
57	270	1	1	873.0
58	285	0	0	950.0
59	150	0	0	1559.0
60	105	0	0	857.0
61	225	1	1	1106.0
62	285	1	1	748.0
63	15	0	0	608.0
64	210	0	1	1745.0
65	195	1	1	1511.0
66	15	1	1	951.0
67	105	1	1	608.0
68	90	1	1	436.0
69	315	1	1	701.0
70	240	0	0	904.0
71	120	1	1	748.0
72	360	0	0	717.0
73	195	0	0	1013.0
74	255	1	1	592.0
75	180	0	0	1387.0
76	30	0	1	576.0
77	270	0	0	1917.0
78	75	0	0	2228.0
79	0	1	1	623.0
80	60	1	0	920.0
81	225	0	0	2867.0
82	345	0	0	732.0
83	45	0	0	639.0
84	330	1	1	624.0
85	300	0	0	966.0
86	240	1	1	857.0
87	135	1	1	794.0
88	345	1	1	1154.0
89	60	0	0	670.0
90	165	1	1	888.0
91	255	0	0	795.0
92	30	1	1	810.0
93	105	0	0	810.0

94	180	1	1	1574.0
95	180	0	0	1402.0
96	315	0	0	1792.0
97	60	0	0	982.0
98	210	1	1	2088.0
99	150	0	0	1122.0
100	255	0	0	1948.0
101	345	0	0	701.0
102	225	0	0	2213.0
103	15	0	0	823.0
104	90	1	1	1412.0
105	270	0	0	3072.0
106	165	1	1	993.0
107	165	0	0	1226.0
108	120	1	1	853.0
109	60	1	1	1226.0
110	120	0	0	1055.0
111	315	1	1	729.0
112	240	0	0	1102.0
113	225	1	1	760.0
114	255	1	1	668.0
115	135	1	1	915.0
116	345	1	1	698.0
117	75	0	0	636.0
118	210	0	0	1816.0
119	195	1	1	962.0
120	45	1	1	1008.0
121	300	1	1	807.0
122	0	1	1	854.0
123	150	1	1	713.0
124	240	1	1	869.0
125	270	1	1	761.0
126	285	1	1	729.0
127	90	0	0	729.0
128	330	1	1	729.0
129	45	0	0	761.0
130	105	1	1	589.0
131	135	0	0	900.0
132	360	0	0	916.0
133	285	0	0	791.0
134	330	0	0	636.0
135	30	0	0	683.0
136	75	1	1	729.0
137	195	0	0	1009.0
138	300	0	0	838.0
139	15	1	1	760.0
140	255	1	1	993.0
141	330	1	1	605.0
142	225	1	1	947.0
143	15	1	1	698.0
144	105	1	1	605.0
145	285	1	1	885.0

146	75	0	0	574.0
147	135	0	0	900.0
148	60	0	0	512.0
149	210	1	1	853.0
150	45	0	0	621.0
151	195	0	0	1319.0
152	120	1	1	775.0
153	255	0	0	683.0
154	150	1	1	1288.0
155	165	0	0	2684.0
156	360	0	0	574.0
157	0	1	1	606.0
158	195	1	1	1551.0
159	330	0	0	761.0
160	150	0	0	1458.0
161	135	1	1	791.0
162	180	1	1	1940.0
163	45	1	1	1955.0
164	105	0	0	1241.0
165	270	0	0	900.0
166	90	1	1	5307.0
167	345	1	1	636.0
168	285	0	0	621.0
169	345	0	0	900.0
170	315	0	0	450.0
171	240	0	0	775.0
172	210	0	0	497.0
173	60	1	1	1040.0
174	315	1	0	636.0
175	240	1	1	1551.0
176	165	1	1	1412.0
177	120	0	0	637.0
178	270	1	1	636.0
179	30	1	1	915.0
180	30	0	0	1040.0

* Total time: 188s
* Score: 173/180.
* Accuracy: 96%
* Time spent on correct answers: 180.693s

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Pre-test time on MRT	Equal variances assumed	,660	,436	-,433	10	,674	-23,516000	54,314635	-144,536548	97,504548
	Equal variances not assumed			-,433	8,540	,676	-23,516000	54,314635	-147,400480	100,368480

TABLE 2. Levene's Test for Equality of Variances is not significant (F=0.660, p=0.436). Equal variances are therefore assumed for male and female subjects. Often reported gender differences favouring males are not statistically significant here (p=0.674).

Descriptive Statistics

Dependent Variable: Improvement %

Group	Subject's gender	Mean	Std. Deviation	N
Control group	Male	11,6000	7,55050	3
	Female	19,6667	15,60299	3
	Total	15,6333	11,81976	6
Experimental group	Male	14,7333	8,25187	3
	Female	34,9667	10,83390	3
	Total	24,8500	14,03578	6
Total	Male	13,1667	7,27919	6
	Female	27,3167	14,64779	6
	Total	20,2417	13,27468	12

TABLE 4. Table shows the groups means for relative improvement in the Mental Rotation Test.

Levene's Test of Equality of Error Variances(a)

Dependent Variable: Improvement %

F	df1	df2	Sig.
,986	3	8	,447

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a Design: Intercept+Group+Gender+Group * Gender

TABLE 5. Levene’s test indicates that the variances are equal.

Test of Homogeneity of Variances

Pre-test time on MRT

Levene Statistic	df1	df2	Sig.
1,073	2	15	,367

TABLE 7. The variances on different groups according to Levene's Test for Equality of Variance's are equal.

ANOVA

Pre-test time on MRT

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11037,186	2	5518,593	,820	,459
Within Groups	100983,018	15	6732,201		
Total	112020,204	17			

TABLE 8. The group means do not differ (Sig = 0,459).

Post Hoc Tests

(I) Videogame experience	(J) Videogame experience	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
NVGP males	NVGP females	-23,516000	47,371585	,885	-152,07240	105,04040
	VGP males	36,662500	47,371585	,746	-91,89390	165,21890
NVGP females	NVGP males	23,516000	47,371585	,885	-105,04040	152,07240
	VGP males	60,178500	47,371585	,465	-68,37790	188,73490
VGP males	NVGP males	-36,662500	47,371585	,746	-165,21890	91,89390
	NVGP females	-60,178500	47,371585	,465	-188,73490	68,37790

TABLE 9. Scheffe - multiple comparisons. Dependent Variable: Pre-test time on MRT

GROUP 1.

Name:	
Age:	
Gender:	Male / Female
Faculty:	
Major Subject:	
Nationality:	

Day	Percentage Completed	Money [$]
1		
2		
3		
4		
5		

GROUP 2.

Name:	
Age:	
Gender:	Male / Female
Faculty:	
Major Subject:	
Nationality:	

Attempt	**Score**
1	
2	
3	
4	
5	
6	
7	
8	

GROUP 3.

Name:	
Age:	
Gender:	Male / Female
Faculty:	
Major Subject:	
Nationality:	

How many years of computer/video game experience do you have? How frequently do you play games?

List some of the games you have played intensively.